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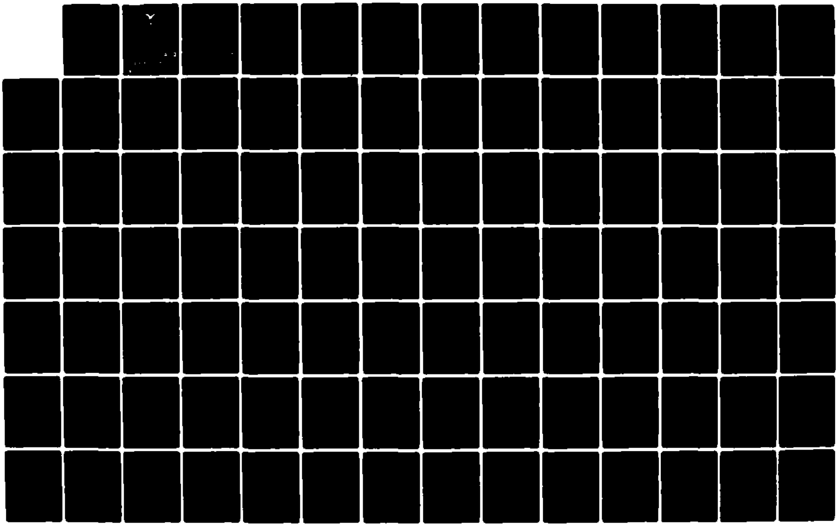

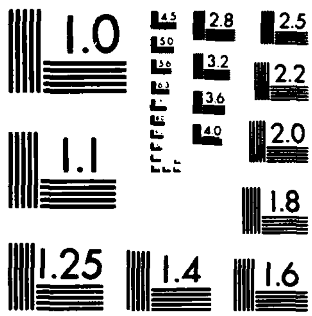

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DEVELOPMENT OF AN OCULOMETER DATA COLLECTION SUBSYSTEM

THESIS

AFIT/GE/EE Nancy L. Wood
Capt USAF

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DEVELOPMENT OF AN OCULOMETER DATA COLLECTION SUBSYSTEM

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

by

Nancy L. Wood, B.S.
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Preface

The Flight Dynamics Lab at Wright-Patterson AFB had procured an oculometer and two SYM-1's and various support equipment to collect data from the oculometer and present the reduced data in readable form. One SYM-1 system had been set up and initially tested but the oculometer was marginally operational. They needed someone to get acquainted with the SYM-1 and write the necessary software for the oculometer data collection subsystem. The project was ideal, because I wanted to do my thesis with the Flight Dynamics Lab and I also desired a software oriented thesis.

It was unknown from the start of the thesis whether the oculometer would be operating correctly or not. Because it was not operating correctly at thesis completion, the software was developed using simulated oculometer data. The data was as realistic as possible and the software written to be easily integrated into a system using the actual oculometer.

I would like to thank the Flight Dynamics Lab, specifically Mr. Bill Klotzback, for making the thesis possible and providing all the support and equipment I needed. Thanks also to Lt Jay Kirchoff and especially Lt Rick Benken, without whose encouragement, advice, and help the SYM-1 wouldn't have been so cooperative and those rough spots would have been a lot rougher.

My deepest thanks and gratitude go to my fianceè, Bruce Crowley, for listening to all my ravings when everything was going wrong and supported me through it all. Thank-you, Bruce.

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Abstract

A SYM-1 microprocessor with dual 5 1/4 inch disk drives was used to develop software to gather and reduce data from a Cubic-Foot Remote Oculometer built by Honeywell, Inc. The primary function of the oculometer is to measure the look direction of a pilot's eye in a ground cockpit simulator. The output of the oculometer used for this effort is eye lookpoint in azimuth and elevation and whether the oculometer is tracking the eye or not. The line-of-sight measurement covers a viewing field of plus and minus 30 degrees in azimuth and zero to plus 30 degrees in elevation. This viewing field is broken into instruments whose boundaries are defined by the data collection subsystem.

The following performance measures are printed out at the end of the data mission:

1. Total dwell time on each instrument.
2. Mean dwell time on each instrument.
3. Proportion of dwell time on each instrument.
4. Proportion of fixations on each instrument.
5. Transition probability from one instrument to another.
6. Number of fixes per minute for each instrument.

The software for the SYM-1 was developed modularly with each module tested separately and then the whole subsystem tested. Simulated oculometer data was used to test the

software. The data collection subsystem was designed to run with minimal knowledge and interaction required by the user.

I. Introduction

Background

This thesis involves the development of software to gather and reduce the output of a device called an oculometer. This is accomplished with a SYM-1 microprocessor system. The following paragraphs briefly describe the operation and uses of the oculometer, and the specific application addressed by the thesis.

An oculometer is an electro-optical device that tracks the eye line-of-sight in two axes without interfering with the subject. The subject, for Air Force applications, is a pilot. The oculometer can be used either in a ground simulator or in an actual aircraft in flight. Uses of the oculometer include two-dimensional tracking where the eye line-of-sight is used for fire control system control, the evaluation of different types of cockpit landing displays, quantifing pilot scan patterns during various phases of flight, and testing and evaluating different types of aircraft cockpit displays.

The oculometer used for this thesis was the "Cubic-Foot Remote Oculometer" built by Honeywell, Inc of Lexington Massachusetts (Ref 1).

The primary function of the oculometer is to measure the look direction of the subjects eye without interfering

with any of his activities. Information on pupil diameter and blink rate can also be obtained.

A sensing subsystem illuminates the subject's eye and collects information on the eye's orientation. A near-infrared (IR) illumination source and an IR-sensitive TV camera are used to obtain a video signal which contains the necessary information about the eye. The IR illumination causes no physical discomfort to the eye and does not cause the pupil diameter to decrease appreciably.

The measurement principle of the eye lookpoint is based on the fact that the angular direction of the eye is proportional to the position of the corneal reflection of the IR light source relative to the center of the pupil. The oculometer can locate the eye and track it throughout a one cubic foot motion box.

The line-of-sight measurement of the oculometer covers a viewing field of plus and minus 30 degrees in azimuth and zero to plus 30 degrees in elevation. The average error in eye tracking is approximately one degree. The oculometer must be calibrated for each subject to eliminate nonlinearities in the viewing field. The parameters for up to six pilots can be stored, so the subject can be tested again without full calibration of the oculometer.

The output of the oculometer is eye lookpoint in azimuth and elevation, pupil diameter, and whether the oculometer is tracking the eye or not. The oculometer loses track of the eye when the pilot moves his eye out of the

range of the tracking equipment. For example, the oculometer will lose track of the eye if the pilot looks behind him. This loss of track is called an out-of-track condition. If the eye image is lost, automatic search procedures are initiated to reaquire it (Ref 2,3).

Oculometer measurements are useful in testing integrated aircraft displays and, coupled with flight path and control input data, to detect subtle differences in piloting techniques during simulated flight (Ref 4). Another use for the oculometer is in the placement of cockpit instruments. Ground and/or flight data can be collected which indicates which instrument needs to be in the center of the pilot's field of view (i.e. the instrument most often looked at) and which instruments need to be in close proximity (i.e. two instruments which have a high number of transitions from one to the other) (Ref 5). The oculometer has been used to evaluate individual displays in the cockpit, and to evaluate changes in displays (Ref 6,7).

The Flight Dynamics Lab at Wright-Patterson Air Force Base, Ohio would like to use the oculometer during 12-18 minute ground data missions in flight simulators to gather data on the pilots lookpoint with respect to cockpit instruments, or segments of instruments. The data will be collected and analyzed by an oculometer data collection subsystem. This data will be used for cockpit design and analysis. Presently, the oculometer data is not being

gathered or reduced. The lab requires thesis completion before the oculometer output can be utilized.

Problem

The problem is to develop an oculometer data collection subsystem that will collect, reduce, print out, and store the data from a data mission.

The following performance measures need to be calculated and stored for each mission:

1. Total dwell time on each instrument or instrument section.
2. Mean dwell time on each instrument or instrument section.
3. Proportion of dwell time spent on each instrument or instrument section.
4. Proportion of fixations on each instrument or instrument section.
5. Transition probability from one instrument to another.
6. Number of fixes per minute for each instrument or instrument section.

The performance measures will be printed out between data missions.

Scope

The oculometer data collection subsystems is to be used in a ground environment in a cockpit simulator. The use of the subsystem in the airborne environment is not addressed.

The cockpit can be subdivided into rectangular or square subsections which can be instruments, segments of instruments, or any area within the viewing field of the oculometer. The subsections are defined by specifying two diagonal corners. The oculometer subsystem design allows for a maximum of 24 instrument subsections to be defined. For an additional seven subsections to be defined, there would be a 25 percent increase in memory space required and in program complexity. Another consideration is that the amount of time between oculometer inputs is 16.67 msec. The more instrument subsections defined, the longer is the time to determine the instrument number for each oculometer input.

The data runs are planned to be from 12-18 minutes long. The data runs are broken into time increments, with each time increment equalling one millisecond. One millisecond was chosen because it was small enough to allow accurate timing of the time between oculometer data samples, which is a minimum of 16.67 milliseconds. A data run of 18 minutes requires 1.08×10^5 time increments. This requires a minimum of three SYM-1 eight bit words, or bytes. Therefore, three bytes were used for the storage of timing information. These three bytes allow for data missions up

to 279 minutes long (3 bytes = 16,777215 time increments = 279 minutes).

Assumptions

The assumptions are that the oculometer used will be the Honeywell Cubic Foot Oculometer with a digital X and Y direction and track/no track outputs, and that the data collection subsystem is to be used in a ground cockpit simulator.

General Approach

Two SYM-1 single board microprocessors were available for the data collection subsystem. The original concept was to have one SYM-1 gather the data from the oculometer, do some preliminary data reduction, and pass the data to the second SYM-1. This SYM-1 would complete the data reduction to produce the final tabular form. As the algorithms were developed, it became apparent that there was adequate time available between data inputs from the oculometer to do all data reduction. There was also enough random access memory (RAM) available on one SYM to store the data reduction programs and the final reduced data table. Therefore, one SYM-1 was used for the data collection subsystem.

The data collection subsystem algorithms were designed using the concepts of structured design. Structured design is a disciplined approach to algorithm design which

simplifies system design by partitioning the system into "black boxes" and organizes these boxes hierarchically. Structured design produces systems that are easy to understand, reliable, flexible, long-lasting, and efficient to operate (Ref 8).

Good design uses the concepts of partitioning and organizing the pieces of the system. Partitioning refers to the division of the problem into small subproblems. Highly interrelated parts of the problem should be in a single black box. A black box is a component with known inputs, known outputs, and generally, a known transform but the contents of the box don't have to be known (Ref 9). The modules were tested with simulated data, since the oculometer was not operational.

Sequence of Presentation

Chapter II describes the equipment used and the configuration of the equipment. The memory map for the SYM-1 is discussed. Chapter III describes how the subsystem was developed using Pascal-like statements, a data flow diagram for the overall program and a structure chart. Each program module is discussed. Chapter IV details the data used to test each module and Chapter V describes the testing of the overall data collection subsystems. Chapter VI describes subsystem timing. Chapter VII details the users guide for operation of the subsystem during ground data missions.

II. Equipment

The following equipment was used to develop the oculometer data collection subsystem:

One SYM-1 single board microprocessor

One Hudson Digital Electronics (HDE) 15 slot 19 inch cage with power supply

Four HDE 8K RAM boards

One HDE 8K EPROM board

One parallel input/output board

One HDE dual 5-1/4 inch disk drive unit

One Hazeltine 1500 CRT terminal

Software:

Editor/assembler in ROM

Disk operating system

Editor on disk

This equipment was purchased for the subsystem before thesis start. Appendix A shows the memory map of the SYM-1.

The unassembled modules are loaded into the Resident Assembler/Editor from disk at memory locations 0200 (hex) to 14FF (hex). When assembled, the modules reside at memory locations 0000 (hex) to 002F hex), 1500 (hex) to 224C (hex) and 6000 (hex) to 7000 (hex). The final data table is from 6000 (hex) to 63FF (hex), and the simulated oculometer input data starts at 6490 (hex). The Resident Assembler Editor and the SYM-1 stack uses memory locations 0A00 (hex) to

0F00 (hex). The memory locations used from 0000 (hex) to 0024 (hex) are used for zero page addressing. The actual program is not stored here. The modules were placed back-to-back, with approximately 20 (hex) memory locations between them.

There is unused memory from 224D (hex) to 5FFF (hex), 7000 (hex) to 7FFF (hex), and 9000 (hex) to 9FFF (hex).

III. Development of the Program

General Development

This section describes the overall subsystem logic and each module. The program was developed by breaking it down into a series of modules, and developing each module into a subroutine. Therefore, the main program is merely a series of calls to subroutines.

The data flow diagram (DFD) is used to partition a system and is a major tool of structured analysis. A DFD is a network representation of a system showing the active components and the data interfaces (Ref 8). The DFD is a tool used to define the proposed logical system. It is useful in identifying the functions of a system and the resultant data transformations (Ref 9).

The basic elements of a DFD are called transforms and are represented by circles. A transform represents transformations of data from one form to another. The data elements themselves are labeled arrows going into the transforms (Ref 10).

Figure 1 shows a data flow diagram for the subsystem. Each module is represented by a transform with the data passed between modules represented by the data elements.

Structure charts are an integral part of structured design methodology. A structure chart shows the partitioning of a system into modules, the hierarhy and

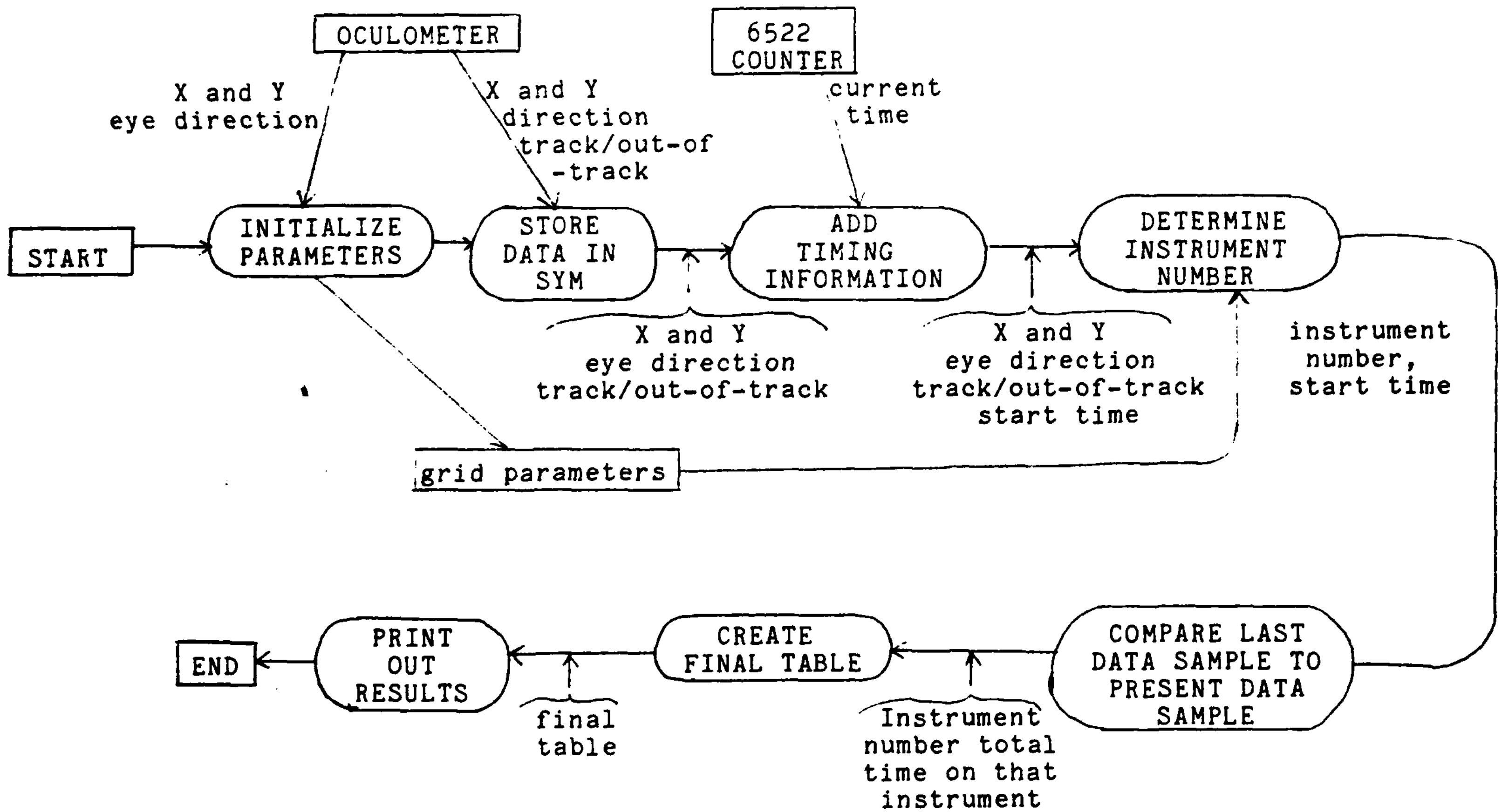

Fig 1. Subsystem Data Flow Diagram

organization of modules, the communication between modules, and the functions of the modules (Ref 8,11).

Each module is represented by a rectangle identified by a name. Modules are connected by arrows. A data element passed between two modules is shown by an arrow with an open circle, and control communication by an arrow with a solid circle. A major decision between two or more modules is designated by a diamond, and a major loop by a semicircle.

Figures 2 and 3 are the structure charts for the Main module and the Print Results module.

A data dictionary is used, among other things to establish a glossary of terms, to provide standard terminology and define all terms, to provide cross-reference capability, and to resolve problems associated with aliases and acronyms (Ref 11). The Initialization module defines the address for all variables used by two or more modules called by the Main module. The remaining variables are declared locally in the declaration section of each module. Therefore, the declaration section of each module serves as a data dictionary.

Each module is discussed, with a Pascal-like description in Appendix C and the assembly language implementation in Appendix D.

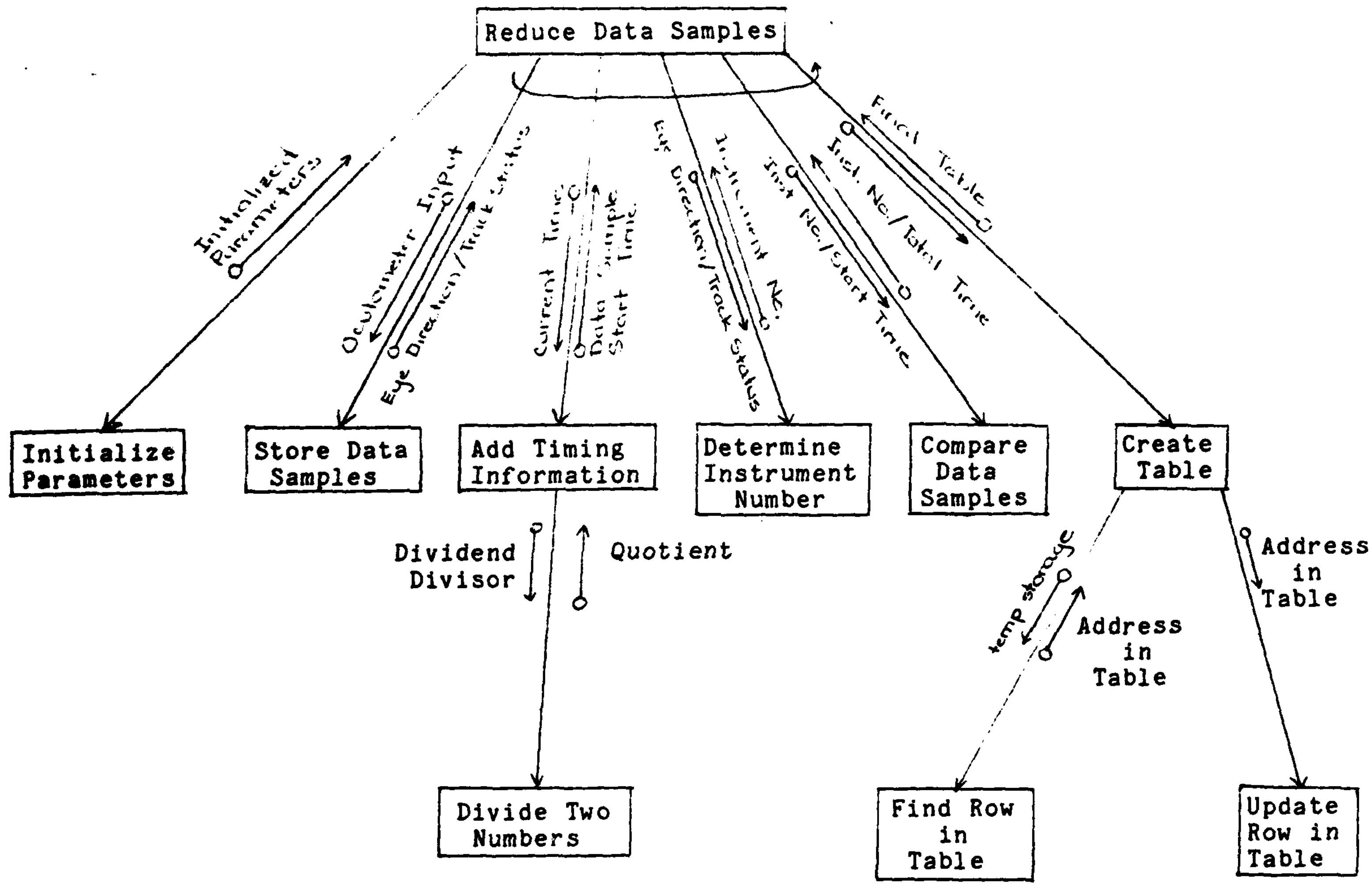

Fig 2. Structure Chart For Main Module

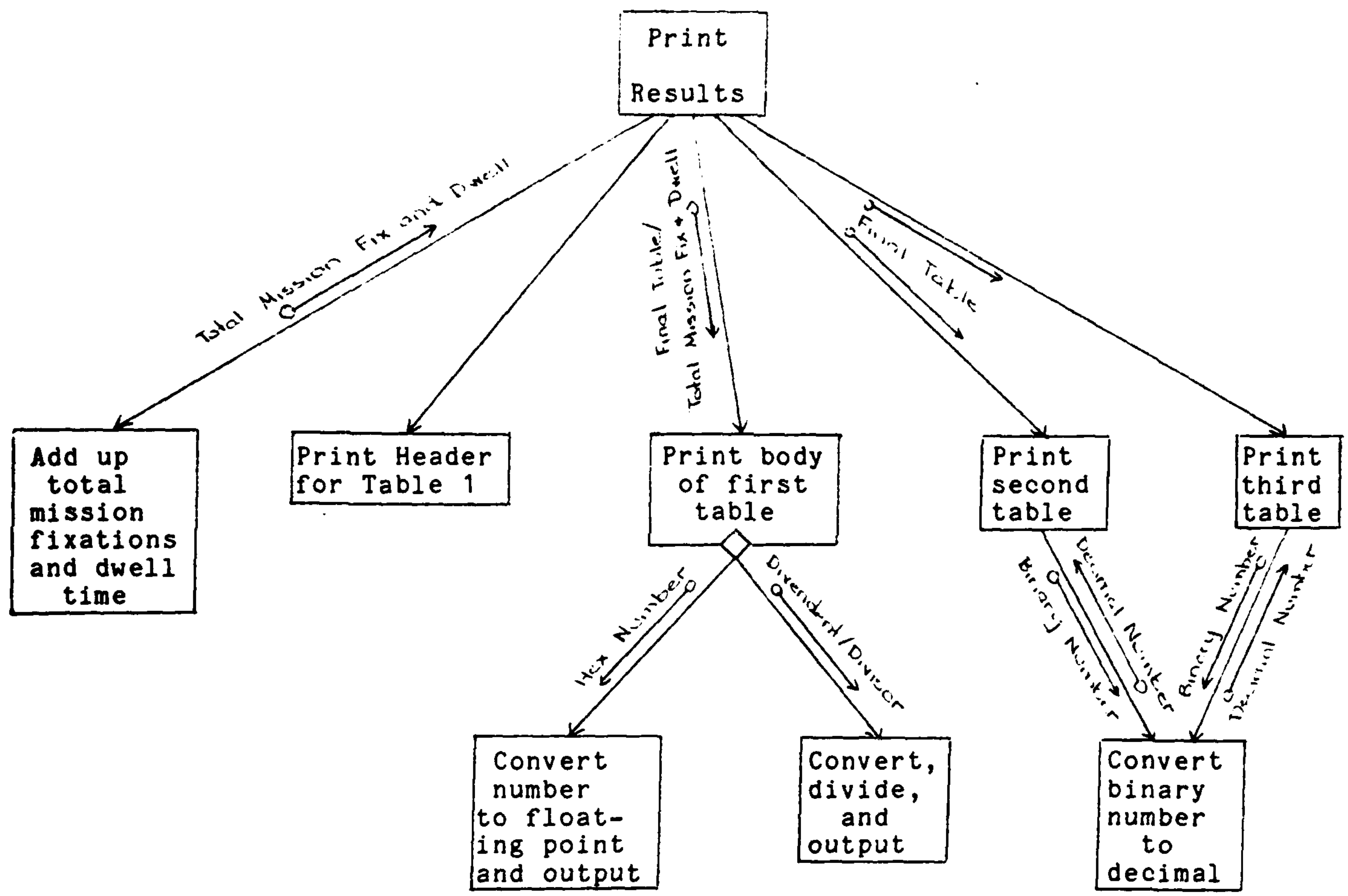

Fig 3. Structure Chart for Print Results Module

Main Subsystem Module

The Initiation module is called by the Main module once at the start of the data mission. Modules Store Data, Add Timing, Determine Instrument Number, Compare Data Samples, and Create Table are called by the Main module each time a data sample comes from the oculometer. Module Print Results is run separately when the data mission is complete. The Main module also has a timing loop to simulate the time between occulometer data samples. The timing loop is approximately 20 milliseconds long. At the end of the loop, the Store Data (Simulated) module is called, followed by Add Timing, Determine Instrument Number, Compare Data Samples and Create Table. Then the Main module checks to see if it is at the end of the array containing the simulated oculometer inputs (see module Store Data). If not, the timing loop is executed again and the process repeated.

Appendix C describes the module in Pascal-like statements. Appendix D lists the assembly language implementation of the module.

Module: Initialize Parameters

This module is called by the Main module before the actual data mission begins. It initializes parameters used in various modules and creates a "grid" of values that defines the boundaries of the instruments, or segments of instruments. The grid parameters were simulated because

actual oculometer data were not available. If the oculometer was available, the grid parameters would be obtained by having the subject look at the four corners of each instrument, and storing the parameters with the associated instrument number.

Table 1 shows each of the parameters, or program variables, that are initialized, the module(s) that uses the parameter, and the value the parameter is initialized to. GRID represents the grid parameters that were simulated.

The SY6522 timer is initialized by the module and starts counting the number of time increments that have passed from the beginning of the data mission. The SY6522 is initialized so it interrupts every 65 milliseconds, or every 65 time increments. At each interrupt, 65 is added to LOTIM, MITIM, and HITIM. These are three bytes that represent the number of time increments from the beginning of the data mission to the last interrupt. The interrupt routine is in the module.

The module also establishes the addresses for all variables used by two or more modules. Variables used by only one module are declared inside that module.

Appendix C describes the module in Pascal-like statements. Appendix D lists the assembly language implementation of the module.

Table I

Subsystem Variable Initialization

Variable	Module(s) That Use Variable	Initialization Value	Description
LSTRT1 LSTRT2 LSTRT3	Compare Data Samples	ØØ	Start time of last data sample
LASTIN	Compare Data Samples	ØØ	Last data sample instrument number
LOTIM MITIM HITIM	Add Timing Information	ØØ	Number of time increments since beginning of data run
TABLE1 TABLE2 TABLE3 TABLE4	Create Table	ØØ	Initialize final data table to zero
OLDIN	Create Table	ØØ	Last instrument number through create table

Module: Store Data

This module is called by the Main module every time a data sample comes from the oculometer. Because the oculometer data is simulated, the Main module calls the Store Data module using a timing loop.

The oculometer output is X eye direction (10 bits), Y eye direction (10 bits), and track/out-of-track status (1 bit). This output is called the current data sample.

When the oculometer is used, the X and Y eye direction is obtained from a connector on the back of the oculometer. Appendix B is the pin connections for the connector. The outputs for pupil diameter are not used.

The oculometer is considered to be "in track" if it is tracking the eye. If the oculometer loses track of the light reflection off the back of the eye, either due to the pilot blinking or moving his eyes outside the tracking area of the oculometer, the oculometer is out-of-track. An out-of-track condition is a logic 0 on the track/out-of-track status line. When the oculometer is out-of-track, the X and Y eye direction remains the same as the last output before the oculometer went out-of-track.

The X direction is stored as 2 bytes, Y direction as 2 bytes, and track/out-of-track status as 1 byte. The oculometer represents negative numbers in two's complement form. Therefore, if the 10th bit from the oculometer is a

zero, the number is positive, and if the 10th bit is one, the number is negative.

Two Store Data modules were developed. Store Data (Oculometer) was designed to be used with the actual oculometer. This module stores X and Y eye direction in 4 bytes by filling in bits 11 through 16 of the high byte of each with either one's or zero's, depending on whether the number is positive or negative. It also stores track/out-of-track status as a one or a zero. These 5 bytes of information are passed to the next module, Add Timing.

The second module is Store Data (Simulated). This module reads simulated X and Y eye direction data and track/out-of-track status from memory and stores them in the same 5 bytes as the Store Data (Oculometer) module.

Appendix C describes both modules in Pascal-like statements. Appendix D lists the assembly language implementation of Store Data (Simulated).

Module: Add Timing

This module adds the necessary timing information to the X and Y eye direction and track/out-of-track status from the Store Data module. The timing information which is added is three bytes that represent the number of time intervals that have elapsed from the beginning of the data mission to the time of the data sample. One time interval is equal to 1 millisecond.

A SY6522, Versatile Interface Adapter, is used for the timing of the data mission. The device is programmed to interrupt the SYM every 65 milliseconds. The SY6522 is initialized in the Initialization module and started at the beginning of the data mission. Every time the SY6522 interrupts, 65 is added to three bytes that represent the number of time intervals that have elapsed since the start of the data mission. These three bytes are named LOTIM, MITIM, and HITIM.

When Add Timing is called, the current 2-byte value of the SY6522 counter is read. This counter counts down from 65000 to zero, interrupts at zero, and automatically reloads 65000 back into the counter and repeats the process. Each count down takes 1 microsecond, therefore the counter will interrupt every 65 milliseconds. Add Timing reads the 2-byte counter, divides the counter value by 1000, subtracts from 65 to get the number of milliseconds that have passed since the last SY6522 interrupt, adds this value to the three bytes LOTIM, MITIM, and HITIM, and stores the resultant 3 bytes with the X and Y direction information of the current data sample.

Therefore, at the end of the Add Timing module, the current data sample consists of X and Y eye direction, track/out-of-track status, and three bytes that represent the number of time intervals from the start of the mission to the current data sample.

Appendix C describes the module in Pascal-like statements. Appendix D lists the assembly language implementation of the module.

Module: Determine Instrument Number

This module takes the X and Y eye direction and track/out-of-track status of the current data sample and defines an instrument number for the sample. The timing information of the data sample remains unchanged.

A grid is created in the Initiation module that defines the boundaries for the cockpit instruments, or segments of instruments. Each instrument is defined by the coordinates of the four corners of the instrument. The grid has a format of upper X, lower X, upper Y, lower Y, and instrument number for each instrument (Fig 2).

The coordinates are 2 bytes each. Each instrument's boundaries are defined in the grid. The order in which the instrument boundaries are stored in the grid is not important. If both the upper and lower values of X or Y are negative, the "lower" value is defined as the lower of the absolute values. For example, if the X coordinates of the instrument are -5 and -7, -5 is the upper X value and -7 is the lower X value. An instrument boundary cannot cross the Y axis. If an instrument does, the instrument must be broken into two sections.

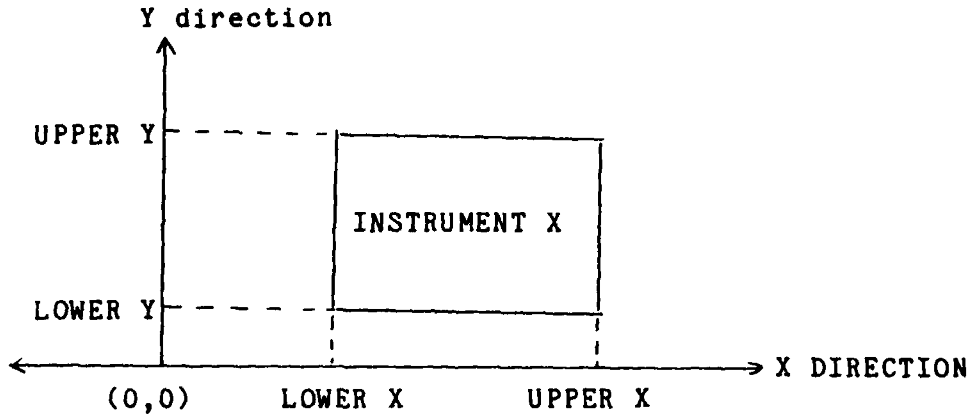

Fig 4. Instrument Boundaries

The instrument boundary coordinates are read and compared to the X and Y eye direction values to see if they are within that instrument. If they are, that instrument number is assigned to the current data sample. If not, the next instrument boundary coordinates in the grid are compared to the X and Y eye direction value. If the X and Y eye direction values are not within any of the defined instruments, the instrument number defined as no instrument is assigned to the present data sample.

If the present data sample is out-of-track, no instrument boundary comparisons are made and the instrument number for the present data sample is zero.

At the completion of the Determine Instrument Number module, the present data sample consists of an instrument

number (1 byte) and the timing information that represents the number of time intervals since the beginning of the data mission (3 bytes).

Appendix C describes the module in Pascal-like statements. Appendix D lists the assembly language implementation of the module.

Module: Compare Data Samples

This module compares the last data sample's instrument number to the present data sample's instrument number.

If the instrument numbers are the same, the current data sample is disregarded because the pilot is still on the same instrument.

If the two instrument numbers are different, the start time (3 bytes) of the last data sample is subtracted from the start time of the current data sample (3 bytes). The result is the total number of time increments spent on the instrument of the last data sample (3 bytes). This total number of time increments and the associated instrument number is sent to the Create Table module. Then the current data sample becomes the last data sample in preparation for the next data sample to go through the module.

Appendix C describes the module in Pascal-like statements. Appendix D lists the assembly language implementation of the module.

Module: Create Table

This module takes each data sample and places the information in a final data table. The data sample consists of an instrument number (INSTNM) and the number of time increments spent on that instrument (TOTIM1, TOTIM2, TOTIM3).

The purpose of the table is to reduce the data to a form that enables the calculation of the performance parameters.

The table is divided into four sections: TABLE1, TABLE2, TABLE3, and TABLE4. Each table contains seven rows. Each row contains information for an instrument, blink, glitch, or data gone. A "glitch" is any data sample where the number of time increments is less than or equal to 50. A "blink" is a data sample with an instrument number of zero (an out-of-track condition) and the number of time increments between 50 and 183. "Data gone" is a data sample with an instrument number of zero and the total number of time increments greater than 183.

Table 2 shows the organization of the information in the data tables. Table 3 shows the format of each of the rows. A '$' in front of a number means the number is in base 16. A "no instrument" condition is defined as instrument number 25. Therefore, 24 instruments can be defined. The total number of fixations is the number of times the instrument was looked at. The accumulated time is the total amount of time spent on that instrument.

Table II

Final Data Table Row Organization

Starting Memory Location	Contents	Starting Memory Location	Contents
TABLE1 + 00	Glitch	TABLE3 + 00	Inst 12
TABLE1 + $22	Blink	TABLE3 + $22	Inst 13
TABLE1 + $44	Data Gone	TABLE3 + $44	Inst 14
TABLE1 + $66	Inst 1	TABLE3 + $66	Inst 15
TABLE1 + $88	Inst 2	TABLE3 + $88	Inst 16
TABLE1 + $AA	Inst 3	TABLE3 + $AA	Inst 17
TABLE1 + $CC	Inst 4	TABLE3 + $CC	Inst 18
TABLE2 + 00	Inst 5	TABLE4 + 00	Inst 19
TABLE2 + $22	Inst 6	TABLE4 + $22	Inst 20
TABLE2 + $44	Inst 7	TABLE4 + $44	Inst 21
TABLE2 + $66	Inst 8	TABLE5 + $66	Inst 22
TABLE2 + $88	Inst 9	TABLE4 + $88	Inst 23
TABLE2 + $AA	Inst 10	TABLE4 + $AA	Inst 24
TABLE2 + $CC	Inst 11	TABLE4 + $CC	Inst 25

Table III

Final Data Table Column Organization

Byte Number	Contents
0	data gone
1 - 25	instruments 1 through 25
26, 27	unused
28	low byte of accumulated time
29	middle byte of accumulated time
30	high byte of accumulated time
31	low byte of total number of fixations
32	high byte of total number of fixations
33	unused

Appendix C describes the module in Pascal-like statements. The module first determines if the current data sample is a glitch. If it is, the glitch row is updated. If it is not a glitch, it next looks at the instrument number. If the instrument number is a zero, either the blink or data gone row is updated. If it was data gone, the instrument number of the current data sample becomes the "last instrument number" (OLDIN). OLDIN was the last instrument looked at. This is used so the probability of transitioning from one instrument to another can be calculated in the final module. If the instrument number was not zero (and it is not a glitch), the appropriate row for that instrument is updated and the instrument number of the current data sample becomes the last instrument number.

Updating a row consists of incrementing the number of fixations, incrementing the column that corresponds to the current last instrument, and adding the number of time increments of the current data sample to the accumulated time.

Appendix D lists the assembly language implementation of the module.

Module: Print Results

This module prints our the performance measures using module prints out the performance measures using the data in the Final Data Table. In the following paragraphs, each of the performance measures are discussed.

1. Total dwell time on each instrument. The three byte accumulated time (byte numbers 28, 29 and 30, see Table 3) is printed out for instruments 1 through 25, data gone, blink and glitch.

2. Mean dwell time on each instrument. The accumulated time for an instrument is divided by the total number of fixations for that instrument. This value is the mean dwell time for that instrument. The mean dwell time is printed out for instruments 1 through 25, data gone, blink and glitch.

3. Proportion of dwell time on each instrument. The accumulated times for instruments 1 through 25 is added up and called total time (TOTIM1, 2 and 3). The accumulated time for an instrument is divided by total time to get the proportion of dwell time on an instrument.

4. Proportion of fixations on each instrument. The total number of fixations for instruments 1 through 25 is added up and called total fixations (TOTFIX1 and 2). The total number of fixations for an ins ·ument is divided by

total fixations to get the proportion of fixations on an instrument.

5. Transitions from one instrument to another. For each instrument 1 through 25, data gone, glitch and blink, the number in the column for each instrument (columns 1 through 25, see Table 3) is printed.

6. Number of fixes per minute for each instrument. The total number of fixations for each instrument is divided by the total number of minutes in the mission.

Floating point routines are used for division and decimal output operations in performance measures 1,2,3,4 and 6. The routines used were derived from floating points routines found in Reference 12. Performance measure 5 requires the data in the table to be printed out in decimal format. The routine to convert from binary to decimal was found in Reference 13.

A description of the module in Pascal-like statements is in Appendix C with the assembly language implementation in Appendix E. Examples of the final printout are in Section V.

IV. Module Validation

The validation of each individual module is discussed in this section. A few of the modules were tested together, but most of the modules were developed and validated independently. The validation of the total subsystem is discussed in Section V.

Testing is an important part of any software development program. Testing is done with the intent of finding errors. There are two major catagories of testing: black-box testing and white-box testing. In black-box testing, the tester views the program as a black box and is unconcerned with the internal structure of the program. It is also known as input/output driven testing because the tests are derived solely from the specifications. White-box testing uses knowledge of the internal structure of the program. The test cases examine the program's logic.

Because it is impossible to test every possible input case, a test of any program must be necessarily incomplete. Therefore, the test cases should try and detect the most errors possible. There are various methodologies used to intelligently select test cases. The methodologistics that were used in the thesis are described briefly below.

White-box testing is also called logic coverage testing. The logic coverage testing used is called decision/ condition coverage. This type of testing ensures that:

1. every statement is executed at least once

2. each decision has a "true" and a "false" outcome at least once

3. each condition in a decision takes on all possible outcomes at least once.

Three types of black box testing were used: equivalence partitioning, boundary-value analysis and error guessing.

In equivalence partitioning, a subset of all inputs is chosen that has the highest probability of finding all errors. This is accomplished by picking test cases that reduce, by more than one, the number of test cases that must be developed, and that cover a large set of other possible test cases.

Boundary-value analysis examines input and output boundary conditions. The boundaries are near the edges of the input and output equivalence classes.

Error guessing is largely an intuitive process. Test cases are designed using intuition and experience to try and expose certain probable types of errors (Ref 14).

Decision/condition coverage was used to test all the modules. Other tests used are stated in the test descriptions of each module.

Module: Main

The Main module was tested with the Initialization and Store Data modules. The Main module prints out a prompt to start the data mission, calls all other modules (except Print Results) and executes a timing loop to simulate the time between data samples. Therefore, the validation of this module consisted of the following:

1. The proper response to the prompt is the letter 's'. Other letters were input to determine if only an 's' would start the data mission (boundary value testing and equivalence partioning).

2. The timing loop was tested during the Timing module. The output of the Timing module was examined to determine if the timing loop was operating correctly.

3. The subroutine calls to each subroutine were added to Main one at a time. As each module was added, the output of that module was examined to determine if the module was operating correctly. The modules were added in the order they are called.

Module: Initialization

The Initialization module establishes addresses for variables used by two or more modules, initializes the SY6522 counter and initializes various variables to zero.

Equivalence partitioning and error guessing techniques were used.

For all variables initialized, the memory locations were examined to ensure their contents were correct.

Correct operation of the SY6522 Counter was examined in the Add Timing module.

Module: Store Data

This module merely stores the X and Y eye direction and track/out-of-track status. For the oculometer simulation, simulated data was stored at specified memory locations and read by the Store Data module. Equivalence partioning was used. Verification of this module consisted of examining the memory locations for X and Y eye direction and track/out-of-track status to verify that the simulated data was being read correctly.

Module: Add Timing

The Add Timing module uses a division subroutine that divides a two-byte dividend by a two-byte divisor (which was 1000 for this application) to get a two-byte quotient and a two-byte remainder. Only the quotient is used by Add Timing. The divisor is 1000 because the timing information from the SY6522 is in microseconds, and the time increment desired is milliseconds.

The test cases for the division subroutine are shown in Appendix E. These cases use the equivalence partitioning technique. The division subroutine was developed and tested separately and then used in Add Timing.

Appendix E also shows the test data from Add Timing. An 18 msec loop was executed and at the end of the loop, the number of time increments from the beginning of the data mission was determined and stored and the timing loop was executed again. The module also tested tne SY6522 counter interrupt routine. The SY6522 was started at the beginning of the module and kept track of the elapsed time intervals. These test cases were acquired from equivalence partitioning and error guessing techniques.

Module: Determine Instrument Number

This module determines an instrument number for each data sample from the X and Y eye direction data and the track/out-of-track status. Data samples were simulated and instrument numbers determined. Boundary value and equivalence partitioning tests were conducted. Appendix E contains the test data samples examined and the test instrument boundaries used.

Module: Compare Data Samples

This module compares the present data sample to the last data sample. If the two instrument numbers are the

same, nothing is done. If they are different, the total time on the last instrument is determined and this time and the last instrument number is sent to the Create Table module.

The module was tested by reading in simulated data samples consisting of an instrument number and the time of the data sample, and outputting instrument numbers and the total time on each instrument. Large and small time values were examined (boundary value testing) and random values of time were tested (equivalence partitioning). The test data is shown in Appendix E.

Module: Create Table

The Create Table module takes the information from the Compare Data Sample module and places the information in a table. The table is from address 6000 through 63FF in the SYM memory. Appendix E shows the data used to test the module. The simulated input data consisted of an instrument number and the time on that instrument. The output was the data in the table. The format of the table was described in Section III. Error guessing and equivalence partitioning were used.

Module: Print Results

This module takes the data from the final table and prints the results out in three tables. The information

printed out is described in Section III. Examples of the final data table are in Appendix G.

The module was tested by using the random numbers in memory locations 6000 (hex) to 6400 (hex). This is the location of the final data table. The values computed and printed were compared to the contents of the memory locations to verify correct module operation. This is equivalence partitioning testing.

V. Subsystem Validation

The subsystem was validated using simulated oculometer input data and simulated parameters for the instrument boundaries. Figure 5 shows the simulated instrument boundaries used. The testing methodogy used was equivalence partitioning. All instruments and out-of-track conditions were simulated. Various time increments on the instruments were examined. The final data table was examined for validity, and the three output tables were compared to the final data table. Appendix G is the actual SYM-1 output of the final data tables and the corresponding printed output.

One value in the three tables is incorrect. This is the number of fixations for glitch in Table 1. There is an error in the floating point routines. This error remained at thesis completion.

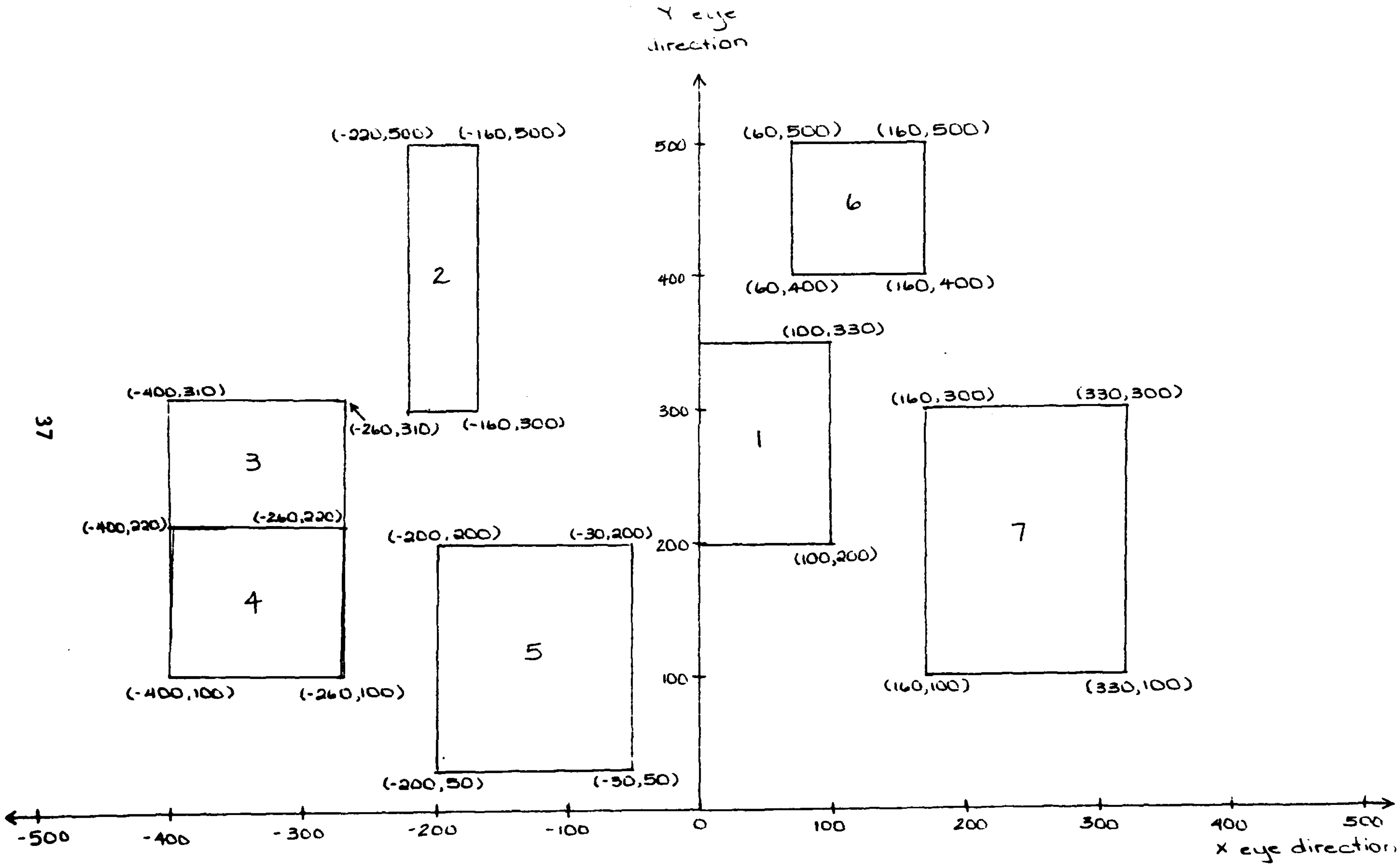

Fig 5. Simulated Instrument Boundaries for Subsystem Validation

VI. Subsystem Timing

The timing of the five modules called by the Main module each time a data sample is input from the SYM is critical. The five modules are Store Data, Add Timing, Determine Instrument Number, Compare Data Samples, and Create Table. These five modules have to be completed in the amount of time between oculometer data sample. The minimum amount of time between data samples is 16.67 milliseconds.

Each module was examined for worst case timing. The worst case timing for each is shown in Table 5.

Table 4

Module Worst Case Timing

Module	Number of Machine Cycles
Store	61
Interrupt	51
Add Timing	2561
Determine Instrument Number	7195
Compare Data Samples	135
Create Table	437
Main	49

The total number of machine cycles is 10489, or 10.489 msec. Therefore, there is more than adequate time between data samples for all six modules.

VII. User's Guide

The following is a guide to using the oculometer data collection subsystem. Items underlined are responses by the SYM-1. Items capitalized are those input by the user. <cr> is a carriage return.

1. Power the SYM-1

   When power is applied, the SYM-1 responds with a "beep"

2. Load disks

   Put the diskette marked "System Disk" into the right hand disk drive and the diskette marked "oculometer subsystem" into the left hand disk drive

3. Assemble subsystem modules

   Hit "Q" on the keyboard. The SYM-1 will respond with a period. Then key in the following sequence of events:

. G 5000 (Note: the space between "G" and "5000" is not keyed in by the user. It is automatically inserted by the SYM-1)

RAE V1.0

FODS COPYRIGHT (a) 1980 HDE INC

0200-0BFC 0C00-0EFC 0E00

0200 0C00

> SET $0200 $1100 $1101 $1300 <cr>

```
0200-1100  1101-1300  0F00
0200 0C00
≥LOAD INIT <cr>

≥AS <cr>
//0000,3028,3028
≥ CL <cr>

≥ LOAD STORE <cr>

≥ AS <cr>
//0000,1A94,1A94
≥ CL <cr>

≥ LOAD TIMDIV <cr>

≥ AS <cr>
//0000,1B44,1B44
≥ CL <cr>

≥LOAD TIMING <cr>

≥ AS <cr>
//0000,1B8E,1B8E
≥ CL <cr>
```

≥ LOAD INSTNM <cr>

≥ AS <cr>

//0000,1C63,1C63

≥ CL <cr>

≥ LOAD COMPAR <cr>

≥ AS <cr>

//0000,1CDD,1CDD

≥ CL <cr>

≥ LOAD UPDAT <cr>

≥ AS <cr>

//0000,2115,2115

≥ CL <cr>

≥ LOAD INCR <cr>

≥ AS <cr>

//0000,2149,2149

≥ CL <cr>

≥ LOAD MASTER <cr>

≥ AS <cr>

//0000,224B,224B

≥ CL <cr>

≥ LOAD MAIN <cr>

≥ AS <cr>

//0000,647A,647A

≥

4. Start data mission

≥ RUN MAIN <cr>

HIT S to START MISSION = S

Any other character than "S" will not start the simulated data mission and another prompt will be printed out. No other user intervention is required until the program is completed and a ">" is printed.

The program using the actual oculometer instead of simulated data will require a set-up program before the data mission starts. This set-up program will establish the instrument boundaries. The boundaries were hand entered for the simulated data runs. The data mission using the oculometer would be started the same way as the simulated data mission (by running the Main module). The actual data mission would end by hitting reset (RST) on the SYM-1 on-board keyboard. The remainder of the User's Guide is the

same for both the simulated and actual data missions.

5. Print out results.

≥ SET $0200 $1300 $1301 $1500 <cr>

0200-1300 1301-1500 0F00

0200 0C00

≥ CL <cr>

≥ LOAD THREE <cr>

≥ AS <cr>

//0000,2028,2028

≥ CL <cr>

≥ LOAD SEVEN <cr>

≥ AS <cr>

//0000,20BB,20BB

≥ CL <cr>

≥ LOAD FPMUL <cr>

≥ AS <cr>

//0000,21CF,21CF

≥ CL <cr>

```
≥ LOAD CONVE <cr>

≥ AS <cr>
// 0000,223F,223F
≥ CL <cr>

≥ LOAD FPDIV <cr>

≥ AS <cr>
//0000,2324,2324
≥ CL <cr>

≥ LOAD FPOUT <cr>

≥ AS <cr>
//0000,241F,241F
≥ CL <cr>

≥ LOAD PRINT <cr>

≥ AS <cr>
//0000,2487,2487
≥ CL <cr>

≥ LOAD TOVAL <cr>
```

```
≥ AS <cr>
//000,283F,283F
≥ CL <cr>

≥ LOAD OUTPT <cr>

≥ AS
//0000,2A1E,2A1E
≥ CL <cr>

>LOAD OUTTB <cr>

≥ AS <cr>
//0000,2BB0,2BB0
≥ CL <cr>

≥ LOAD RESTB <cr>

≥ AS <cr>
//0000,2D4F,2D4F
 ≥ CL <cr>

≥ LOAD OUTTC <cr>

≥ AS <cr>
//0000,3730,3730
≥ CL <cr>
```

≥ LOAD OUTTD <cr>

≥ AS <cr>

//0000,3929,3929

≥ CL <cr>

≥ LOAD BINDEC <cr>

≥ AS <cr>

//0000,39D7,39D7

≥ CL <cr>

≥ LOAD FINAL <cr>

≥ AS <cr>

//0000,3A01,3A01

≥ RUN FINAL <cr>

All three final tables will print out.

VIII. Recommendations

The oculometer data collection subsystem needs further development to be used with an oculometer. The following additional software is required:

1. Interface with the oculometer. The data from the oculometer needs to be accessed and stored in the SYM-1.

2. Establishment of instrument boundaries. Before the data mission is started, the pilot will look at two diagonal corners of each desired instrument. The X and Y eye direction values of the two corners are used to establish and store the instrument boundaries.

3. Generation of oculometer interrupt. Every time the oculometer generates a new data sample, the SYM-1 needs to be interrupted so the data can be stored by the SYM-1 and used.

4. Correction of the floating point error in Table 1.

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APPENDIX A

SYM-1 Memory Map

Memory Location	Boundary	Contents
FFFF		
		SYM-1 Operating System Locations
	FF80	
EFFF		
		Resident Assembler/Editor
DFFF		
CFFF		
BFFF		
		Resident Assembler/Editor
AFFF		
		Disk controller
9FFF		
		4K RAM
8FFF		
		SUPERMON (SYN-1 Operating System)
7FFF		
6FFF		8K RAM
5FFF		
4FFF		8K EPROM
3FFF		
2FFF		RAM
1FFF		
	0F00	
		Resident Assembler/Editor, Stack
	0A00	
		RAM
0000		

APPENDIX B

Oculometer Connector for Digital Data Output

Connector type: ITT # KPTØ2E2Ø - 41S

Pin Number	Pin Output
1	bit 1 - MSB of X eye direction
2	bit 2
3	bit 3
4	bit 4
5	bit 5
6	bit 6
7	bit 7
8	ground
9	bit 8
10	bit 9
11	bit 10 - LSB of X eye direction
12	clock
13	+5 volts DC
14	bit 1 - MSB of Y eye direction
15	bit 2
16	bit 3
17	bit 4
18	bit 5
19	bit 6
20	bit 7
21	ground
22	bit 8
23	bit 9
24	bit 10 - LSB of Y eye direction
25	clock
26	+5 volts DC
27	bit 1 - LSB of pupil diameter
28	bit 2
29	bit 3
30	bit 4
31	bit 5
32	bit 6
33	bit 7
34	ground
35	bit 8
36	bit 9
37	bit 10 - LSB of pupil diameter
38	clock
39	+5 volts DC
40	not connected
41	not connected

APPENDIX C

Pascal-like Description of Modules

1. Module Main Subsystem

Variable definitions:

INIT : location of Initialization module

STORE : location of Store Data module

TIMING : location of Add Timing module

DETNUM : location of Determine Instrument Number module

COMPAR : location of Compare Data Samples module

TABLE : location of Create Table module

TIMING : a timing loop 20 msec long

```
WRITELN ('HIT S TO START MISSION')

READ(CHAR)

IF CHAR = S THEN (* start the mission *)

     BEGIN

          INIT (* call INIT module *)

          COUNT : = 0 (* look at beginning of array
                          that holds simulated
                          oculometer output *)

          TIMLOOP (* execute timing loop that is 20 msec
                    long *)

          STORE (* call STORE module *)

          TIMING (* call TIMING module *)

          DETNUM (* call DETNUM module *)

          COMPAR (*call COMPAR module *)
```

TABLE (* call TABLE module *)

IF we are at the end of simulated oculometer output THEN Main module is done

ELSE go back to TIMING

END

ELSE (*character is not an S*) print out another prompt to start the mission

2. Module Initialization

Variable definitions:

LSTRT1, LSTRT2, LSTRT3 : start time of last data sample

LASTIN : instrument number of last data sample

LOTIM, MITIM, HITIM : number of time increments since beginning of data run

OLDIN : last instrument through create table

Declare all variables in two or more modules

LSTRT1 : = 0

LSTRT2 : = 0

LSTRT3 : = 0

LASTIN : = 0

LOTIM : = 0

MITIM : = 0

HITIM : = 0

OLDIN : = 0

Final Data Table : = 0

Initialize 6522 Counter

Store interrupt routine

3. Module Store Data (Simulated)

Variable definitions:

DATA[I] : array that contains simulated oculometer output in the format of XDIRH, XDIRL, YDIRH, YDIRL, TRACK. The end of the array is a 'D'.

XDIRH : high byte of X eye direction

XDIRL : low byte of X eye direction

YDIRH : high byte of Y eye direction

YDIRL : low byte of Y eye direction

TRACK : track/out-of-track status; = 0 if out-of-track

COUNT : pointer to keep track of where you are in the DATA array. It is initialized to zero in the Main module.

```
XDIRH : = DATA [COUNT]

COUNT : = COUNT + 1

YDIRL : = DATA [COUNT]

COUNT : = COUNT + 1

YDIRH : = DATA [COUNT]

COUNT : = COUNT + 1

YDIRL : = DATA [COUNT]

COUNT : = COUNT + 1

TRACK : = DATA [COUNT]

COUNT : = COUNT + 1
```

Module Store Data (Oculometer)

Variable definitions:

XDIRL : low 8 bits of X direction

XDIRH : hi 8 bits of X direction

YDIRL : low 8 bits of Y direction

YDIRH : hi 8 bits of Y direction

TRACK : track/out-of-track status

READ bits 1-8 of X direction into bits 0-7 of XDIRL

READ bits 9-10 of X direction into bits 0-1 of XDIRH

READ bits 1-8 of Y direction into bits 0-7 of YDIRL

READ bits 9-10 of Y direction into bits 0-1 of YDIRH

IF bit 1 of XDIR = 1 THEN (* it was a negative
    number *) set bits 2-7 of XDIRH to 1

ELSE (* it was a positive number *) set bits 2-7 of
    XDIRH to 0

IF bit 1 of YDIRH = 1 THEN (* it was a negative
    number *) set bits 2-7 of YDIRH to 1

ELSE (*it was a positive number *) set bits 2-7 of
    YDIRH to 0

IF oculometer out-of-track THEN TRACK : = 0

ELSE (* oculometer is in track *) TRACK : = 1

4. Module Add Timing

Variable definitions:

LOTIME : low byte of time intervals elapsed to the
    last 6522 interrupt

MITIME : middle byte of time intervals elapsed to the
    last 6522 intervals

HITIME : high byte of time intervals elapsed to the
    last 6522 interrupt

LCOUNT : low byte of 6522 counter

HCOUNT : high byte of 6522 counter

START1 : low byte of number of time intervals elapsed
    to the current data sample

START2 : middle byte of number of time intervals elapsed to the current data sample

START3 : high byte of number of time intervals elapsed to the current data sample

READ HCOUNT and LCOUNT

Divide HCOUNT, LCOUNT by 1000 and subtract from 65

Add this to LOTIME, MITIME, HITIME and store result in START1, START2, START3

5. Module Determine Instrument Number

Variable definitions:

XDIR : X eye direction of current data sample

YDIR : Y eye direction of current data sample

GRID[I] : array with instrument boundaries followed by the instrument number with a format of upper X, lower X, upper Y, lower Y, instrument number. There is an 'E' at the end of the array

NOINST : instrument number for no instrument

INST : the data sample's instrument number

TRACK : track/out-of-track status of current data sample. It is equal to zero if data sample is out-of-track

XH : storage for upper X boundary from GRID

XL : storage for lower X boundary from GRID

YH : storage for upper Y boundary from GRID

YL : storage for lower Y boundary from GRID

CURINS : storage for instrument number from GRID

```
I : = 1
IF TRACK = 0 THEN
     INST := 0
ELSE
     WHILE not at the end of GRID DO
          BEGIN
               XH : = GRID [I]
               I : = I + 1
               XL : = GRID [I]
               I : = I + 1
               YH : = GRID [I]
               I : = I + 1
               YL : = GRID [I]
               I : = I + 1
               CURINS : = GRID [I]
               I : = I + 1
               IF  XH - XDIR < 0 THEN
                   it cannot be in that instrument so
                   go back to WHILE and get another
                   set of instrument boundaries
               IF  XL - XDIR > 0 THEN
                   go back to WHILE and get another
                   set of instrument boundaries
               IF  YH - YDIR < 0 THEN
                   go back to WHILE and get another
                   set of instrument boundaries
               IF  YL - YDIR > 0 THEN
                   go back to WHILE and get another
                   set of instrument boundaries
               (* If the data sample made it through
               all the tests, it was within that
               instrument's boundaries *)
```

```
INST : = CURINS

END (* WHILE *)

(* If reached the end of GRID and no instrument number
 was found, define the instrument as no instrument *)

IF reached the end of GRlD THEN INST : = NOINST
```

6. Module Compare Data Samples

Variable definitions:

INST : current data sample's instrument number

LASTIN : last data sample's instrument number

START : start time of current data sample

LSTRT : start time of last data sample

TOTIM : total number of time increments on LASTIN. This is sent to the next module

INSTNM : instrument number sent to the next module with TOTIM

```
IF LASTIN ≠ INST THEN

     BEGIN

          TOTIM : = START - LSTRT

          INSTNM : = LASTIN

          LASTIN : = INST

          LSTRT : = START

     END

(* ELSE if they are not equal, disregard the data
 sample *)
```

7. Module Create Table

```
Variable definitions:

INSTNM : instrument number of the current data sample

TOTIM : total number of time increments of the current
        current data sample

OLDIN : instrument number of the last data sample
        through the module if the sample was not a
        glitch or a blink.

GLITCH, BLINK, DATAGN, INS1..25 : each represents the
     starting address of a row in the table for that
     instrument.  Each row is 33 bytes long.

IF TOTIM < 50 THEN (* the data sample is a glitch *)

     BEGIN

          increment GLITCH + 31, 32 (* 31 and 32 are
               bytes for number of fixations *)

          increment GLITCH + OLDIN (* determine which
               instrument was transitioned from *)

          add TOTIM to GLITCH + 28, 29, 30 (* bytes
               28, 29, and 30 represent the amount
               of time spent on that instrument *)

     END

ELSE  (*it is not a glitch*)

     IF INSTNM = 0 THEN (* it is out-of-track *)

          IF TOTIM ≤ 183 THEN

          (* it is a blink *)

               BEGIN

                    increment BLINK + 31, 32

                    increment BLINK + OLDIN

                    add TOTIM to BLINK + 28, 29, 30

               END
```

```
ELSE (*it is data gone *)
     BEGIN
          increment DATAGN + 31, 32
          increment DATAGN + OLDIN
          add TOTIM to BLINK + 28, 29, 30
          OLDIN : = INSTNM
     END
ELSE (*it is not out-of-track so it is an
        instrument*)
     BEGIN
          X : = INSTNM
          increment INSX + 31, 32
          increment INSX + OLDIN
          add TOTIM to INSX + 28, 29, 30
          OLDIN : = INSTNM
     END
```

8. Module: Print Results

Variable definitions:

TABLE[I] : location of final data table

NEXTINST : difference in location between the same data in two instruments

ACCTIME : location of accumulated time

FIX : location of the total number of fixations for an instrument

TOTIME : total accumulated time for all instruments

TOTFIX : total number of fixations for all instruments

MINUTES : total number of minutes in a mission

FIXMIN : number of fixes per minute for an instrument

TRANS[I] : number of transitions from instrument I to the instrument you are examining

MEANDWL : mean dwell time for an instrument

PROPDWL : proportion of dwell time on an instrument

PROPFIX : proportion of fixations for an instrument

```
(*print out total dwell time on each instrument*)
DO WHILE there are instruments
    BEGIN
        WRITELN (TABLE[ACCTIME])
        (*go to the next instrument*)
        ACCTIME := ACCTIME + NEXTIN
    END
(*print out mean dwell time on each instrument*)
DO WHILE there are instruments
    BEGIN
        MEANDWL := TABLE[ACCTIME]/TABLE[FIX]
        WRITELN (MEANDWL)
        (*go to next instrument*)
        ACCTIME := ACCTIME + NEXTINST
        FIX := FIX + NEXTINST
    END
(*print proportion of dwell time on each instrument*)
DO WHILE there are instruments
```

```
    BEGIN
        TOTIME := TOTIME = TABLE[ACCTIME]
        ACCTIME := ACCTIME = NEXTINST
    END
DO WHILE there are instruments
    BEGIN
        PROPDWL := TABLE[ACCTIME]/TOTIME
        WRITELN(PROPDWL)
        (*go to the next instrument*)
        ACCTIME := ACCTIME + NEXTINST
    END
(*print proportion of fixations on each instrument*)
DO WHILE there are instruments
    BEGIN
        TOTFIX := TOTFIX + TABLE[FIX]
        FIX := FIX + NEXTINST
    END
DO WHILE there are instruments
    BEGIN
        PROPFIX := TABLE[FIX]/TOTFIX
        WRITELN (PROPFIX)
        (*go to next instrument*)
        FIX := FIX + NEXTINST
    END
(*print transition probabilities*)
DO WHILE there are instruments
```

```
    BEGIN
        FOR I := 1 to 25 DO
                WRITELN(TRANS[I]
        (*go to the next instrument*)
        FIX := FIX + NEXTIN
    END
(*print number of fixes per minute for each instrument*)
DO WHILE there are instruments
    BEGIN
        FIXMIN := TABLE[FIX]/MINUTES
        WRITELN(FIXMIN)
        (*go to next instrument*)
        FIX := FIX + NEXTINST
    END
```

APPENDIX D

Assembly Language Implementation of Modules

1. Module: Initialization

```
%LOAD INIT

%FF
0010                .BA $1823
0020                .OS
0040  ;DEFINE ADDRESSES FOR ALL VARIABLES USED BY TWO MORE
0050  ;MODULES. THE FOLLOWING ARE USED BY STORE DATA AND
0051  ;DETERMINE INST NUM.
0060  XDIRH         .DS 1         ;HI BYTE OF X EYE DIRECTION
0070  XDIRL         .DS 1         ;LO BYTE OF X EYE DIRECTION
0080  YDIRH         .DS 1         ;HI BYTE OF Y EYE DIRECTION
0090  YDIRL         .DS 1         ;LO BYTE OF Y EYE DIRECTION
0100  TRACK         .DS 1         ;TRACK/OUT-OF-TRACK STATUS
0110  ;THE FOLLOWING ARE USED BY ADD TIMING AND COMPARE
0120  START1        .DS 1         ;3 BYTES OF TIMING INFORMATION
0130  START2        .DS 1         ; FOR CURRENT DATA SAMPLE
0140  START3        .DS 1 ;
0150  ;THE FOLLOWING ARE USED BY INST NUM AND COMPARE
0160  INSTNM        .DS 1         ;INST NUM SENT TO CREATE TABLE
0161  ;THE FOLLOWING ARE USED BY TIMING AND CREATE TABLE
0170  TOTIM1        .DS 1         ;TOTAL TIME SPENT
0180  TOTIM2        .DS 1         ; ON INSTNM
0190  TOTIM3        .DS 1 ;
0200  ;THE FOLLOWING IS USED BY COMPARE AND CREATE TABLE
0210  INST          .DS 1         ;INST NUM OF CURRENT DATA SAMPLE
0220  ;THE FOLLOWING ARE USED BY INITIALIZATION AND COMPARE
0221  ;AND CREATE TABLE
0230  LSTRT1        .DS 1         ;START TIME OF
0240  LSTRT2        .DS 1         ; LAST DATA SAMPLE
0250  LSTRT3        .DS 1 ;
0260  LASTIN        .DS 1         ;INST NUM OF LAST DATA SAMPLE
0270  ;THE FOLLOWING ARE USED BY INITIALIZATION AND ADD TIMING
0280  LOTIM         .DS 1         ;NUMBER OF TIME INCREMENTS
0290  MITIM         .DS 1         ; SINCE BEGINNING OF
0300  HITIM         .DS 1         ; DATA RUN
0310  ;THE FOLLOWING ARE USED BY INITIALIZATION AND CREATE TABLE
0320  LAST          .DS 1         ;LAST INST THROUGH CREATE TABLE
0330  TABLE1        .DE $6000     ;STORAGE LOCATIONS
0340  TABLE2        .DE $6100     ; FOR FINAL
0350  TABLE3        .DE $6200     ; DATA TABLE
0360  TABLE4        .DE $6300 ;
0370  ;SIMULATED GRID WITH A FORMAT OF UPPER X, LOWER X, UPPER Y,
0371  ;LOWER Y, INSTRUMENT NUMBER.  AN INSTRUMENT CANNOT CROSS THE Y
0372  ;AXIS.  IF BOTH LOWER AND UPPER X ARE NEG, THE UPPER X IS THE
0373  ;ONE CLOSEST TO THE Y AXIS.
0380  GRID          .BY 00 $64 $00 $00 $01 $5E $00 $C8 01
0390  GRI1          .BY $FF $60 $FF $24 $01 $F4 $01 $2C 02
```

```
0400  GRI2      .BY $FE $EC $FE $70 $01 $36 $00 $DC 03
0410  GRI3      .BY $FE $EC $FE $70 $00 $DC $00 $64 04
0420  GRI4      .BY $FF $E2 $FF $38 $00 $C8 $00 $32 05
0430  GRI5      .BY $00 $A0 $00 $3C $01 $F4 $01 $90 06
0440  GRI6      .BY $01 $4A $00 $A0 $01 $2C $00 $64 07 'E'
0449            .BA $19D6
0450  ;THE FOLLOWING ARE USED FOR INITIALIZATION    THE 6522
0460  ACR       .DE $A00B      ;6522 AUXILIARY CONTROL REGISTER
0470  LLATCH    .DE $A006      ;6522 LO LATCH
0480  HLATCH    .DE $A005      ;6522 HI LATCH AND COUNTER
0490  LCOUNT    .DE $A004      ;6522 LO COUNTER
0500  IER       .DE $A00E      ;6522 INTERRUPT ENABLE REG
0510  IRQVEC    .DE $A67E      ;SYSTEM INTERRUPT VECTOR
0520  ACCESS    .DE $8B86      ;UNPROTECT SYSTEM RAM
0530  LINT      .BY $00        ;LO BYTE OF INTERRUPT LOCATION
0540  HINT      .BY $30        ;HI BYTE OF INTERRUPT LOCATION
0550  ;
0560  INIT      LDA #00        ;INITIALIZE THE
0570            STA LSTRT1     ; NECCESSARY
0580            STA LSTRT2     ; PARAMETERS TO
0590            STA LSTRT3     ; ZERO
0600            STA LASTIN
0610            STA LOTIM
0620            STA MITIM
0630            STA HITIM
0640            STA LAST
0650  ;INITIALIZE FINAL DATA TABLE TO ZERO
0660            LDY #00
0670  GO1       LDA #00
0680            STA TABLE1,Y
0690            INY
0700            CPY #$FF
0710            BNE GO1
0720            LDY #00
0730  GO2       LDA #00
0740            STA TABLE2,Y
0750            INY
0760            CPY #$FF
0770            BNE GO2
0780            LDY #00
0790  GO3       LDA #00
0800            STA TABLE3,Y
0810            INY
0820            CPY #$FF
0830            BNE GO3
0840            LDY #00
0850  GO4       LDA #00
0860            STA TABLE4,Y
0870            INY
0880            CPY #$FF
0890            BNE GO4
0900            LDY #$FF
0910            LDA #00
0920            STA TABLE1,Y
0930            STA TABLE2,Y
0940            STA TABLE3,Y
```

```
0950            STA TABLE4,Y
0960 ;INITIALIZE 6522 COUNTER
0970            JSR ACCESS
0980            SEI
0990            LDA LINT
1000            STA IRQVEC   ;LOAD ADDRESS OF
1010            LDA HINT
1020            STA IRQVEC+1          ; INTERRUPT ROUTINE
1030            LDA #$C0
1040            STA IER      ;INTIALIZE IER
1050            LDA #$40
1060            STA ACR      ;INITIALIZE ACR
1070            LDA #$E8     ;LOAD 65000 INTO
1080            STA LLATCH   ; TIMER. TIMER
1090            LDA #$FD     ; IS NOW RUNNING
1100            STA HLATCH
1110            CLI  ;ENABLE INTERRUPTS
1120            RTS
1130 ;INTERRUPT ROUTINE TO ADD 65 TO THE CURRENT
1140 ;NUMBER OF TIME INTERVALS ELAPSED
1150            .BA $3000
1151            PHA
1160            LDA #$41
1170            CLC
1180            ADC LOTIM
1190            STA LOTIM
1200            LDA #$00
1210            ADC MITIM
1220            STA MITIM
1230            LDA #00
1240            ADC HITIM
1250            STA HITIM
1260            LDA LCOUNT   ;CLEAR 6522 INTERRUPTS
1270            CLI  ;ENABLE SYM INTERRUPTS
1275            PLA
1280            RTI
1290            .EN
```

?. Module: Store Data

```
>LOAD STORE

>PR
 0010                .BA $6490
 0020                .OS
 0040  ;SIMULATED OCULOMETER INPUT DATA IN FORM OF TRACK,X,Y
 0050  DATA          .BY 01 00 $3C 01 $2C 01 00 $3C 01 $2C 01 00 04 01 $2C
 0060  DATA1         .BY 01 00 04 01 $2C 01 00 04 01 $2C 01 00 04 01 $2C
 0070  DATA2         .BY 01 00 04 01 $2C 01 00 04 01 $2C 01 00 04 01 $90
 0080  DATA3         .BY 01 00 00 01 $90 01 00 00 01 $90 01 00 00 01 $90
 0090  DATA4         .BY 01 $FF $9C 00 $3C 01 $FF $9C 00 $3C 01 $FF $9C 00 $3C
 0100  DATA5         .BY 01 $FF $9C 00 $3C 01 $FF $9C 00 $3C 01 $FF $9C 00 $3C
 0110  DATA6         .BY 01 $FF $9C 00 $3C 00 $FF $9C 00 $3C 00 $FF $9C 00 $3C
 0120  DATA7         .BY 00 $FF $9C 00 $3C 01 $FF $9C 00 $64 01 $FF $9C 00 $64
 0130  DATA8         .BY 01 $FF $9C 00 $64 01 $FF $9C 00 $64 01 $FE $D4 00 $C8
 0140  DATA9         .BY 01 $FE $D4 00 $C8 01 $FE $D4 00 $C8 01 $FE $D4 $01 $2C
 0150  DATA10        .BY 01 $FE $D4 $01 $2C 01 $FE $D4 $01 $2C 01 $FE $D4 $01 $2C
 0160  DATA11        .BY 01 $FE $D4 $01 $2C 01 $FE $D4 $01 $2C 01 00 00 01 $90
 0170  DATA12        .BY 01 00 00 01 $90 01 00 00 01 $90 01 00 00 01 $90
 0180  DATA13        .BY 01 00 00 01 $90 01 00 $64 00 $64 01 00 $64 00 $64
 0190  DATA14        .BY 01 00 $64 00 $64 01 00 $64 00 $64 00 00 01 $90 01 'D'
 0200                .BA $1A70
 0210  XDIRH         .DE $1823
 0220  XDIRL         .DE $1824
 0230  YDIRH         .DE $1825
 0240  YDIRL         .DE $1826
 0250  TRACK         .DE $1827
 0260  STORE         LDA DATA,Y
 0270                STA TRACK
 0280                INY
 0290                LDA DATA,Y
 0300                STA XDIRH
 0310                INY
 0320                LDA DATA,Y
 0330                STA XDIRL
 0340                INY
 0350                LDA DATA,Y
 0360                STA YDIRH
 0370                INY
 0380                LDA DATA,Y
 0390                STA YDIRL
 0400                INY
 0410                RTS
 0420                .EN
```

3. **Division routine called by Add Timing module**

```
>LOAD TIMDIV

>PR
0010                .BA $1AA4
0020                .DS
0040  DIVHI         .DS 1          ;HIGH BYTE OF DIVISOR
0050  DIVLO         .DS 1          ;LOW BYTE OF DIVISOR
0060  REMHI         .DS 1          ;HI BYTE OF REMAINDER
0070  REMLO         .DS 1          ;LO BYTE OF REMAINDER
0080  QUOHI         .DS 1          ;HI BYTE OF DIVIDEND/QUOTIENT
0090  QUOLO         .DS 1          ;LO BYTE OF DIVIDEND/QUOTIENT
0091  COUNT         .DS 1
0100  ; THIS ROUTINE DIVIDES A TWO-BYTE DIVIDEND BY A
0110  ;2-BYTE DIVISOR TO GET A 2-BYTE QUOTIENT AND A 2-BYTE
0120  ;REMAINDER
0130  START         LDA #00
0140                STA REMHI      ;INITIALIZE ALL VARIABLES
0150                STA REMLO
0151                STA COUNT
0200                LDA #$03
0210                STA DIVHI
0220                LDA #$E8
0230                STA DIVLO
0250                JSR SHIFT
0260  LOOP          SEC
0261                LDA REMLO
0270                SBC DIVLO
0280                STA REMLO
0290                LDA REMHI      ;REM-DIV
0300                SBC DIVHI
0310                STA REMHI
0320                BCS POS        ;IF CARRY=1, RESULT WAS POS
0330                LDA REMLO
0340                ADC DIVLO
0350                STA REMLO
0360                LDA REMHI
0370                ADC DIVHI
0380                STA REMHI
0390                JSR SHIFT
0400                JMP GO
0410  POS           LDA #01
0430                ORA QUOLO
0440                STA QUOLO
0441                JSR SHIFT
0450  GO            INC COUNT
0460                LDA #15
0461                CMP COUNT
0470                BNE LOOP
0480                RTS
0490  ; SUBROUTINE TO SHIFT THREE BYTES LEFT
0500  SHIFT         ASL QUOLO      ;SHIFT LEFT-0 INTO LSB
```

```
0510         BCC ONE      ;IF CARRY=0, DON'T NEED
0520         ASL QUOHI    ; TO BRING BIT OVER
0530         LDA #01
0540         ORA QUOHI
0550         STA QUOHI    ;BRING CARRY OVER
0560         JMP TWO
0570  ONE    ASL QUOHI
0580  TWO    BCC THREE
0590         ASL REMLO
0600         LDA #01
0610         ORA REMLO
0620         STA REMLO
0630         JMP FOUR
0640  THREE  ASL REMLO
0650  FOUR   BCC FIVE
0660         ASL REMHI
0670         LDA #01
0680         ORA REMHI
0690         STA REMHI
0700         JMP SIX
0710  FIVE   ASL REMHI
0720  SIX    DEC
0721         RTS
0730         .EN
```

Module: Add Timing

```
>LOAD TIMING

>PR
0010                .BA $1B50
0020                .OS
0040  DIVIS         .DE $1AAB    ;ROUTINE TO DIVIDE
0050  QUOHI         .DE $1AA8    ;HI BYTE OF DIVIDEND/QUOTIENT
0060  QUOLO         .DE $1AA9    ;LO BYTE OF DIVIDEND/QUOTIENT
0070  LOTIME        .DE $1834    ;LO BYTE OF NUM OF TIME INTERVALS
0080  MITIME        .DE $1835    ;MIDDLE BYTE OF TIME INTERVALS
0090  HITIME        .DE $1836    ;HI BYTE OF TIME INTERVALS
0100  HLATCH        .DE $A005    ;6522 HI LATCH
0110  LCOUNT        .DE $A004    ;6522 LO COUNTER
0120  START1        .DE $1828
0130  START2        .DE $1829
0140  START3        .DE $182A
0150  TIMING        SEI
0151  ;THIS MODULE DETERMINES THE NUMBER OF TIME INTERVALS THAT HAVE
0152  ;ELAPSED FROM THE BEGINNING OF THE DATA RUN TO THE CURRENT
0153  ;DATA SAMPLE.  IT CALLS DIVIS, WHICH DIVIDES TWO BYTES BY TWO
0154  ;BYTES.
0160                LDA HLATCH   ;READ HI BYTE OF COUNTER
0170                STA QUOHI
0180                LDA LCOUNT   ;READ LO BYTE OF COUNTER
0190                STA QUOLO
0200                JSR DIVIS    ;DIVIDE COUNT BY 1000
0210  ; SUBTRACT RESULT FROM 65 TO FIND
0220  ;NUMBER OF TIME INTERVALS ELAPSED
0230                SEC
0240                LDA #$41     ;LO BYTE OF 65
0250                SBC QUOLO    ;$41-QUOLO
0260                STA QUOLO
0270                LDA #$00     ;HI BYTE OF 65
0280                SBC QUOHI
0290                STA QUOHI
0300  ; NOW ADD TO THE CURRENT NUMBER
0310  ;OF TIME INTERVALS ELAPSED
0320                LDA LOTIME
0330                CLC
0340                ADC QUOLO
0350                STA START1   ;START TIME OF CURRENT DATA SAMPLE
0360                LDA MITIME
0370                ADC QUOHI
0380                STA START2
0390                LDA #00
0400                ADC HITIME
0410                STA START3
0420                CLI
0430                RTS
0440                .EN
```

7. Module: Determine Instrument Number

```
>LOAD INSTNM

>PR
0010  ;FIND INSTRUMENT NUMBER
0020  ;
0030  ;  THIS SUBROUTINE WILL TAKE THE X AND Y DATA AND TRACK
0040  ;DATA FROM THE CURRENT DATA SAMPLE AND DEFINE THE
0050  ;INSTRUMENT NUMBER OF THE DATA SAMPLE.
0060  ;  THE X DATA IS TWO BYTES AND IS CALLED XDIRH (HIGH
0070  ;ORDER BYTE) AND XDIRL (LOW ORDER BYTE).  THE Y DATA
0080  ;IS YDIRL AND YDIRH.  THE INSTRUMENTS ARE
0090  ;DEFINED BY THE X AND Y VALUES OF THE DIAGONAL CORNERS,
0100  ;CALLED UPPER AND LOWER X VALUES AND UPPER AND LOWER
0110  ;Y VALUES.  THESE 4 VALUES ARE TWO BYTES EACH AND ARE
0120  ;STORED IN THE GRID.
0130  ;
0140              .BA $1BB0
0160              .DS
0250  COMH        .DS 1
0260  COML        .DS 1
0270  GRIDH       .DS 1
0280  GRIDL       .DS 1
0290  RESH        .DS 1        ;DEFINED IN SUBTRACT SUBROUTINE
0300  RESL        .DS 1
0310  E           .BY 'E'
0320  GRID        .DE $1838
0330  INST        .DE $182B    ;INST NUM THAT IS DETERMINED
0340  XDIRH       .DE $1823    ;X EYE DIRECTION OF
0350  XDIRL       .DE $1824    ; CURRENT DATA SAMPLE
0360  YDIRH       .DE $1825    ;Y EYE DIRECTION OF
0370  YDIRL       .DE $1826    ; CURRENT DATA SAMPLE
0371  TRACK       .DE $1827    ;TRACK/OUT-OF-TRACK STATUS
0380  NOINST      .BY 25       ;INST NUM OF NO INSTRUMENT
0390  BUFFER      .DE $3500
0430  ;
0730  ;  FIND THE INSTRUMENT NUMBER
0740  ; DETERMINE IF IT IS OUT-OF-TRACK
0741              TXA
0742              PHA  ;SAVE X REGISTER FOR BUFFER LOCATION
0750              LDX #00      ;INITIALIZE X
0760              LDA TRACK    ;PUT TRACK BYTE IN A
0770              BNE FIND     ;IF ZERO, SET INST NUM TO ZERO
0780              LDA #00
0790              STA INST
0800              JMP END
0810  FIND        LDA GRID,X   ;GET HIGH BYTE OF
0820              STA GRIDH    ; UPPER X VALUE
0830              INX
0840              LDA GRID,X   ;GET LOW BYTE OF
0850              STA GRIDL    ; UPPER X VALUE
0860              LDA XDIRH    ;COMH=XDIRH
```

```
0870            STA COMH
0880            LDA XDIRL     ;COML=XDIRL
0890            STA COML
0900            JSR SUBTRA    ;XH-X
0910            BCC BACK1     ;NOT IN GRID IF RESULT NEG
0920  ; GET TWO BYTES OF LOWER X VALUE
0930            INX
0940            LDA GRID,X    ;GET HIGH BYTE OF
0950            STA GRIDH     ; LOWER X VALUE
0960            INX
0970            LDA GRID,X    ;GET LOW BYTE OF
0980            STA GRIDL     ;LOWER X VALUE
0990  ; ALREADY HAVE XDIRL IN COML AND XDIRH IN COMH
1000            JSR SUBTRA    ;XL-X
1010            BCS BACK2     ;NOT IN GRID IF RESULT POS
1020  ; GET TWO BYTES OF UPPER Y VALUE
1030            INX
1040            LDA GRID,X    ;HIGH BYTE OF
1050            STA GRIDH     ;UPPER Y VALUE
1060            INX
1070            LDA GRID,X    ;LOW BYTE OF
1080            STA GRIDL     ; UPPER Y VALUE
1090            LDA YDIRH     ;COMH=YDIRH
1100            STA COMH
1110            LDA YDIRL     ;COML=YDIRL
1120            STA COML
1130            JSR SUBTRA    ;YL-Y
1140            BCC BACK3     ;NOT IN GRID IF REULT NEG
1150  ; GET TWO BYTES OF LOWER Y VALUE
1160            INX
1170            LDA GRID,X    ;HIGH BYTE OF
1180            STA GRIDH     ; LOWER Y VALUE
1190            INX
1200            LDA GRID,X    ;LOW BYTE OF
1210            STA GRIDL     ; LOWER Y VALUE
1220            JSR SUBTRA    ;YL-Y
1230            BCS BACK4     ;NOT IN GRID IF RESULT POS
1240  ; HAVE FOUND THE INSTRUMENT
1250            INX
1260            LDA GRID,X
1270            STA INST
1280            JMP END
1290  BACK1     INX
1300            INX
1310  BACK2     INX
1320            INX
1330  BACK3     INX
1340            INX
1350  ; STILL NEED TO FIND INSTRUMENT NUMBER
1360  BACK4     INX  ;LOOK AT INSTR NUM
1365            INX  ;LOOK AT NEXT NUMBER
1370            LDA GRID,X
1380            CMP E
1390            BNE FIND      ;BACK TO BEGINNING IF NOT AN E
1400            LDA NOINST
1410            STA INST
```

```
1420  END         PLA
1421              TAX
1440              RTS
1450  ;
1460  ;SUBROUTINE SUBTRACT
1470  ;  NEED THE FOLLOWING VARIABLES FOR THIS SUBROUTINE:
1480  ;COMH - HIGH BYTE OF DATA SAMPLE
1490  ;COML - LOW BYTE OF DATA SAMPLE
1500  ;GRIDH - HIGH BYTE OF GRID PARAMETER
1510  ;GRIDL - LOW BYTE OG GRID PARAMEYER
1520  ;
1530  SUBTRA      SEC   ;SET CARRY
1540              LDA GRIDL
1550              SBC COML      ;SUBTRACT LOW ORDER BYTES
1560              STA RESL      ;STORE RESULT
1570              LDA GRIDH
1580              SBC COMH      ;SUBTRACT HIGH ORDER BYTES
1590              STA RESH      ;STORE RESULT
1600              RTS
1610              .EN
```

5. Module: Compare Data Samples

```
.LOAD COMPAR

:PR
0010  ;  PROGRAM COMPARE
0020  ;  THIS PROGRAM WILL COMPARE THE LAST DATA SAMPLE TO THE
0030  ;PRESENT DATA SAMPLE.  IF THE INSTRUMENT NUMBER IS THE SAME, DO
0040  ;NOTHING.  IF THEY ARE DIFFERENT, SET THE STOP TIME OF THE
0050  ;LAST DATA SAMPLE EQUAL TO THE START TIME OF THE CURRENT DATA
0060  ;SAMPLE AND SEND THE LAST DATA SAMPLE TO THE BUFFER.  THE
0070  ;CURRENT DATA SAMPLE BECOMES THE LAST DATA SAMPLE.
0080  ;
0090                .BA $1C80
0100                .OS
0111  INSTNM        .DE $182B     ;INST NUM INTO COMPARE
0120  INST          .DE $182F     ;INST NUM TO CREATE TABLE
0130  START1        .DE $1828     ;CURRENT DATA SAMPLE
0140  START2        .DE $1829     ; TIMING INFORMATION
0150  START3        .DE $182A
0160  LASTIN        .DE $1833     ;LAST DATA SAMPLE INST NUM
0170  LSTRT1        .DE $1830     ;START TIME OF LAST
0180  LSTRT2        .DE $1831     ; DATA SAMPLE
0190  LSTRT3        .DE $1832
0200  TOTIM1        .DE $182C     ;TOTAL TIME SPENT
0210  TOTIM2        .DE $182D     ; ON INSTNM
0220  TOTIM3        .DE $182E
0230  BUFFER        .DE $3500
0240  TEST          .DE $641C     ;TEST BYTE USED IN MAIN MODULE
0250  ;
0260  ;COMPARE LAST DATA SAMPLE TO PRESENT DATA SAMPLE
0270  ;
0271                LDA #00
0272                STA TEST
0280                LDA INSTNM
0290                CMP LASTIN    ;IS INST=LASTIN?
0300                BEQ END
0310                LDA LASTIN    ;IF NO, SEND INFO TO BUFFER
0311                STA INST
0320                STA BUFFER,X
0330                INX
0340  ;
0350  ;SUBTRACT TO FIND TOTAL TIME AND SEND INFO TO BUFFER.
0360  ;3-BYTE SUBTRACT: START-LSTRT1, TO GET TOTAL TIME ON
0370  ;THAT INSTRUMENT.
0380  ;
0390                SEC  ;SET CARRY
0400                LDA START1
0410                SBC LSTRT1    ;SUBTRACT LOW ORDER BYTES
0420                STA TOTIM1
0430                STA BUFFER,X        ;STORE RESULT IN BUFFER
0440                INX
```

```
0450            LDA START2
0460            SBC LSTRT2   ;SUBTRACT MIDDLE BYTES
0470            STA TOTIM2
0480            STA BUFFER,X          ;STORE RESULT IN BUFFER
0490            INX
0500            LDA START3
0510            SBC LSTRT3   ;SUBTRACT HI ORDER BYTES
0520            STA TOTIM3
0530            STA BUFFER,X          ;STORE RESULT IN BUFFER
0540            INX
0560  ;SET NEW LAST DATA SAMPLE
0570  ;
0580            LDA INSTNM   ;LASTIN=INSTNM
0590            STA LASTIN
0600            LDA START1   ;LSTRT1=START1
0610            STA LSTRT1
0620            LDA START2   ;LSTRT2=START2
0630            STA LSTRT2
0640            LDA START3   ;LSTRT3=START3
0650            STA LSTRT3
0651            LDA #01
0652            STA TEST
0660  END       RTS
0670            .EN
```

7. Update-routine called by Create Table module

```
>LOAD UPDAT

>PR
0010                  .BA $2000
0020                  .OS
0040  ;THIS PROGRAM IS CALLED BY MASTER.
0050  ;IT WILL UPDATE THE PROPER COLUMNS IN THE TABLE.
0060  TABLE1          .DE $6000
0070  TABLE2          .DE $6100
0080  TABLE3          .DE $6200
0090  TABLE4          .DE $6300
0100  COLTT1          .BY 28          ;COLUMN FOR HI BYTE OF TIME
0110  COLTT2          .BY 29          ;COLUMN FOR MID BYTE OF TIME
0120  COLTT3          .BY 30          ;COLUMN FOR LO BYTE OF TIME
0130  COLFXL          .BY 31          ;COL FOR NUM OF FIXATIONS
0140  COLFXH          .BY 32
0150  TEMP            .DE $2160
0160  LAST            .DE $1837
0170  TOTIM1          .DE $182C
0180  TOTIM2          .DE $182D
0190  TOTIM3          .DE $182E
0200  UPDAT1          CLC
0210                  TXA  ;TRANSFER X TO ACC
0220                  ADC COLTT1
0230                  TAX  ;TRANSFER ACC TO X
0240                  CLC
0250                  LDA TOTIM1
0260                  ADC TABLE1,X
0270                  STA TABLE1,X
0280                  INX
0290                  LDA TOTIM2
0300                  ADC TABLE1,X
0310                  STA TABLE1,X
0320                  INX
0330                  LDA TOTIM3
0340                  ADC TABLE1,X
0350                  STA TABLE1,X
0360                  INX
0370                  CLC
0380                  LDA #01
0390                  ADC TABLE1,X
0400                  STA TABLE1,X
0410                  INX
0420                  LDA #00
0430                  ADC TABLE1,X
0440                  STA TABLE1,X
0450                  LDX TEMP
0460                  CLC
0470                  TXA
0480                  ADC LAST
0490                  TAX
```

```
        INC TABLE1,X
        RTS
UPDAT2  CLC
        TXA  ;TRANSFER X TO ACC
        ADC COLTT1
        TAX  ;TRANSFER ACC TO X
        CLC
        LDA TOTIM1
        ADC TABLE2,X
        STA TABLE2,X
        INX
        LDA TOTIM2
        ADC TABLE2,X
        STA TABLE2,X
        INX
        LDA TOTIM3
        ADC TABLE2,X
        STA TABLE2,X
        INX
        CLC
        LDA #01
        ADC TABLE2,X
        STA TABLE2,X
        INX
        LDA #00
        ADC TABLE2,X
        STA TABLE2,X
        LDX TEMP
        CLC
        TXA
        ADC LAST
        TAX
        INC TABLE2,X
        RTS
UPDAT3  CLC
        TXA  ;TRANSFER X TO ACC
        ADC COLTT1
        TAX  ;TRANSFER ACC TO X
        CLC
        LDA TOTIM1
        ADC TABLE3,X
        STA TABLE3,X
        INX
        LDA TOTIM2
        ADC TABLE3,X
        STA TABLE3,X
        INX
        LDA TOTIM3
        ADC TABLE3,X
        STA TABLE3,X
        INX
        CLC
        LDA #01
        ADC TABLE3,X
        STA TABLE3,X
```

```
        INX
        LDA #00
        ADC TABLE3,X
        STA TABLE3,X
        LDX TEMP
        CLC
        TXA
        ADC LAST
        TAX
        INC TABLE3,X
        RTS
UPDAT4  CLC
        TXA  ;TRANSFER X TO ACC
        ADC COLTT1
        TAX  ;TRANSFER ACC TO X
        CLC
        LDA TOTIM1
        ADC TABLE4,X
        STA TABLE4,X
        INX
        LDA TOTIM2
        ADC TABLE4,X
        STA TABLE4,X
        INX
        LDA TOTIM3
        ADC TABLE4,X
        STA TABLE4,X
        INX
        CLC
        LDA #01
        ADC TABLE4,X
        STA TABLE4,X
        INX
        LDA #00
        ADC TABLE4,X
        STA TABLE4,X
        LDX TEMP
        CLC
        TXA
        ADC LAST
        TAX
        INC TABLE4,X
        RTS
        .EN
```

8. Incr-routine called by Create Table module

```
>LOAD INCR

>PR
 0010                .BA $2130
 0020                .OS
 0050  TEMP          .DE $2160
 0060  TEMSTO        .DS 1
 0090  INCR          DEC TEMSTO    ;STORAGE FOR
 0091                LDA TEMSTO
 0100                BEQ DONE      ; INSTRUMENT NUMBER
 0110                CLC
 0120                LDA #$22
 0130                ADC TEMP      ;TEMP IS THE
 0140                STA TEMP      ; PROPER ADDRESS
 0150                JMP INCR      ; IN THE TABLE
 0160  DONE          LDX TEMP
 0170                RTS
 0180                .EN
```

9. Module: Create Table

```
>LOAD MASTER

>PR
0010 ;MASTER ALGORITHM.  THIS ALGORITHM WILL PUT THE INFORMATION
0020 ;IN THE DATA SAMPLES INTO THE FINAL DATA TABLE.  THE DATA
0030 ;COMING IN IS IN THE FORM OF:
0040 ;      INSTNM = INSTRUMENT NUMBER
0050 ;      TOTIM1,TOTIM2,TOTIM3 = NUMBER OF TIME INTERVALS SPENT
0060 ;ON THAT INSTRUMENT.
0070 ;
0080                 .BA $2160
0090                 .OS
0110 TEMP            .DS 1
0120 ; DEFINE SPACE FOR TABLE
0130 TABLE1          .DE $6000     ;FOR GLICH,BLINK,DATA GONE
0140                 ;AND INST 1-4
0150 TABLE2          .DE $6100     ;FOR INSTS 5-11
0160 TABLE3          .DE $6200     ;FOR INSTS 12-18
0170 TABLE4          .DE $6300     ;FOR INSTS 19-25
0180 UPDAT1          .DE $2005
0190 UPDAT2          .DE $2049
0200 UPDAT3          .DE $208D
0210 UPDAT4          .DE $20D1
0220 INCR            .DE $2131
0230 TEMSTO          .DE $2130
0240 COMMA           .DE $833A
0250 INST            .DE $182F     ;INST NUM THROUGH MASTER
0261 ;   THIS IS LASTIN FROM MODULE COMPARE
0270 TOTIM1          .DE $182C     ;TOTAL NUMBER OF TIME INCREMENTS
0280 TOTIM2          .DE $182D     ; ON INSTNM
0290 TOTIM3          .DE $182E
0291 LAST            .DE $1837     ;LAST INST NUM THROUGH CREATE TABLE
0300 ;
0310 MASTER          TXA
0320                 PHA   ;SAVE X REGISTER
0330                 LDA TOTIM3
0340                 BNE NOGLIT    ;IF TOTIM3 NOT 0,CANNOT BE A GLITCH
0350                 LDA TOTIM2
0360                 BNE NOGLIT    ;IF TOTIM2 NOT 0,CANNOT BE A GLITCH
0370                 SEC
0380                 LDA #$32
0390                 SBC TOTIM1    ;IF TOTIM1>50 IT IS
0400                 BCC TEST1     ; NOT A GLITCH
0410                 LDX #00
0420                 LDA #00
0430                 STA TEMP
0440                 JSR UPDAT1    ;UPDATE TABLE
0450                 JMP END
0460 ;NOW SEE IF THE INST NUM IS OUT-OF-TRACK
0470 TEST1           LDA INST      ;ALREADY KNOW TOTIM2+3 = 0.
0480                 BNE FIND      ;IF INSTNM NOT ZERO,IT IS AN INST
```

```
          SEC
          LDA #$B7
          SBC TOTIM1     ;183-TOTIM1
          BCC NOGLIT     ;NO GLICH IF TOTIM1>183
          LDX #$22       ;IF TOTIM1L<183, IT IS A BLINK
          LDA #$22
          STA TEMP
          JSR UPDAT1
          JMP END
NOGLIT    LDA INST
          BNE FIND       ;GO TO FIND IF IT IS AN INST
          LDX #$44       ;ELSE IT IS OUT-OF-TRACK
          LDA #$44
          STA TEMP
          JSR UPDAT1
          LDA INST
          STA LAST
          JMP END
; FIND THE CORRECT SPOT IN TABLE FOR THAT INST
FIND      SEC
          LDA #$04
          SBC INST       ;IF INSTNM<5, THEN THAT INST
          BCC TEST2      ; IS IN TABLE1
          LDA #$66
          STA TEMP
          LDA INST
          STA TEMSTO
          JSR INCR       ;FIND CORRECT ROW IN TABLE
          JSR UPDAT1
          LDA INST
          STA LAST
          JMP END
TEST2     SEC
          LDA #$0B
          SBC INST       ;IF INSTNM<12, THEN THAT INST
          BCC TEST3      ; IS IN TABLE2
          LDA #$00
          STA TEMP
          SEC
          LDA INST
          SBC #$04
          STA TEMSTO
          JSR INCR
          JSR UPDAT2
          LDA INST
          STA LAST
          JMP END
TEST3     SEC
          LDA #$12
          SBC INST       ;IF INSTNM<18, THAT INST IS
          BCC TEST4      ; IN TABLE3
          LDA #$00
          STA TEMP
          SEC
          LDA INST
```

```
                SBC #$0B
                STA TEMSTO
                JSR INCR
                JSR UPDAT3
                LDA INST
                STA LAST
                JMP END
TEST4           SEC
                LDA #$1A
                SBC INST       ;IF INSTNM<26, IT IS
                BCC TEST5      ; IN TABLE4
                LDA #$00
                STA TEMP
                SEC
                LDA INST
                SBC #$12
                STA TEMSTO
                JSR INCR
                JSR UPDAT4
                LDA INST
                STA LAST
                JMP END
TEST5           JSR COMMA      ;HAVE AN ERROR
END             PLA
                TAX
                RTS
                .EN
```

10. Module: Main Subsystem

```
:LOAD MAIN

:PR
0010                .BA $6400
0020                .OS
0040  DATA          .DE $6490     ;LOCATION OF SIMULATED OCULOMETER DATA
0050  INIT          .DE $19D8     ;INITIALIZATION MODULE
0060  STORE         .DE $1A70     ;STORE DATA FROM OCULOMETER
0070  TIMING        .DE $1B50
0080  INSTNM        .DE $1BB8
0090  COMPAR        .DE $1C80
0100  MASTER        .DE $2161
0110  OUTCHR        .DE $8A47     ;OUTPUT A CHARACTER
0120  INCHR         .DE $8A1B     ;INPUT A CHARACTER
0130  CRLF          .DE $834D     ;CARRIAGE RETURN AND LINE FEED
0140  START         .BY 'HIT S TO START MISSION-'
0150  COUNT1        .BY 23
0160  S             .BY 'S'
0170  COUNT2        .DS 1
0180  LO            .DS 1
0190  HI            .DS 1
0191  TEST          .DS 1         ;TEST TO SEE IF MODULE MASTER IS CALLED
0200  D             .BY 'D'
0210  ;PRINT OUT PROMPT TO START PROGRAM
0220  MAIN          JSR CRLF
0230                LDX #00
0240  LOOP1         LDA START,X
0250                JSR OUTCHR
0260                INX
0270                CPX COUNT1
0280                BNE LOOP1
0290                JSR INCHR
0300                CMP S
0310                BNE MAIN
0311                LDX #00
0320  ;DATA MISSION HAS STARTED
0330                JSR INIT      ;TIMER IS RUNNING
0340                LDY #00       ;DON'T USE Y IN ANY OTHER MODULES
0350  ;THE FOLLOWING IS A TIMING LOOP TO SIMULATE
0360  ;OCULOMETER DATA SAMPLES
0370  NEXT          LDA #$40      ;LO BYTE OF 832
0380                STA LO
0390                LDA #$03      ;HI BYTE OF 832
0400                STA HI
0410  LOOP2         SEC  ;THIS LOOP IS APPROX
0420                LDA LO        ; APPROX 20 MSEC LONG
0430                SBC #01
0440                STA LO
0450                NOP
0460                LDA HI
```

```
0470                 SBC #00
0480                 STA HI
0490                 BNE LOOP2
0500  ;NOW STORE A DATA SAMPLE
0510                 JSR STORE
0520                 JSR TIMING
0530                 JSR INSTNM
0540                 JSR COMPAR
0541                 LDA TEST
0542                 BEQ OVER
0550                 JSR MASTER
0560  OVER           LDA DATA,Y
0570                 CMP D          ;ARE AT END OF DATA?
0580                 BNE NEXT       ;IF NOT, TIME NEXT SAMPLE
0581                 SEI
0590                 RTS
0600                 .EN
```

The following modules are used by the Print Results module.

11. Module: Three

```
LOAD THREE

PR
;THREE
;  THIS IS A GROUPING OF THREE ROUTINES USED BY
;THE PRINT RESULTS ROUTINE.
             .BA $2000
             .OS
VALUE        .DE $0000
;ROTATE RIGHT
;  THIS ROUTINE ROTATES Y (INDEX REGISTER) BYTES TO
;THE RIGHT.  THE X REGISTER IS THE LOCATION OF THE
;LS BYTE OF THE DATA TO BE ROTATED.
ROTATL       CLC  ;CLEAR CARRY
ROTL         ROL VALUE,X  ;ROTATE THE BYTE LEFT
             DEY  ;DECREMENT BYTE COUNTER
             BNE MORRTL    ;NOT ZERO, CONTINUE ROTATE
             RTS  ;DONE, RETURN
MORRTL       INX  ;ADVANCE MEMORY POINTER
             JMP ROTL      ;CONTINUE TO ROTATE LEFT
;
;ROTATE RIGHT
;  THE SAME PARAMETERS ARE USED AS IN ROTATE LEFT.
ROTATR       CLC  ;CLEAR CARRY
ROTR         ROR VALUE,X  ;ROTATE THE BYTE RIGHT
             DEY  ;DECREMENT BYTE COUNTER
             BNE MORRTR    ;NOT ZERO, CONTINUE ROTATE
             RTS  ;DONE,RETURN
MORRTR       DEX  ;DECREMENT MEMORY POINTER
             JMP ROTR      ;CONTINUE ROTATE RIGHT
;
;COMPLEMENT
;  THIS PERFORMS THE TWO'S COMPLEMENT OF Y NUMBER
;OF BYTES. THE X REGISTER CONTAINS THE LS BYTE OF THE
;VALUE TO BE COMPLEMENTED
COMPLM       SEC  ;SET CARRY
COMPL        LDA #$FF      ;LOAD $FF FOR COMPLEMENT OP
             EOR VALUE,X   ;COMPLEMENT BYTE
             ADC #$00      ;IF CARRY=1, TWO'S COMPLEMENT
             STA VALUE,X   ;STORE BYTE IN MEMORY
             INX  ;ADVANCE MEMORY POINTER
             DEY  ;DECREMENT BYTE COUNTER
             BNE COMPL     ;NOT ZERO, CONTINUE
             RTS  ;RETURN TO CALLING PROGRAM
             .EN
```

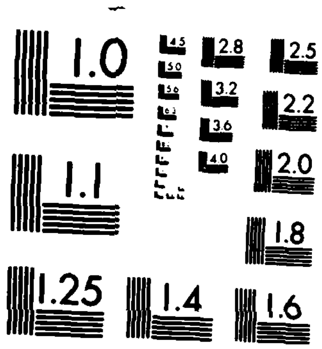
AD-A124 700 DEVELOPMENT OF AN OCULOMETER DATA COLLECTION SUBSYSTEM (U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGINEERING N L WOOD DEC 82 2/2

UNCLASSIFIED AFIT/GE/EE/82D-72 F/G 9/2 NL

END

DATE FILMED

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

2. Module: Seven

```
LOAD SEVEN

PP
0010                .BA $2030
0030                .OS
0040  ;SUBROUTINE SEVEN
0050  ;  THESE ARE SEVEN ROUTINES NEEDED FOR THE FLOATING
0060  ;POINT ROUTINES.
0070  ;
0080  FMPNT         .DE $0000      ;FROM POINTER
0090  TOPNT         .DE $0002      ;TO POINTER
0100  SIGNS         .DE $0006      ;SIGN INDICATOR
0110  FPLSW         .DE $0008      ;FPACC LS BYTE
0120  FPNSW         .DE $0009      ;FPACC NEXT SINGNIFICANT BYTE
0130  FPMSW         .DE $000A      ;FPACC MOST SIGNIFICANT BYTE
0140  MCAND0        .DE $000C      ;MULTIPLICATION WORK AREA
0150  FOPLSW        .DE $0010      ;FPOP LEAST SIGNIFICANT BYTE
0160  FOPNSW        .DE $0011      ;FPOP NEXT SIGNIFICANT BYTE
0170  FOPMSW        .DE $0012      ;FPOP MOST SIGNIFICANT BYTE
0180  FOPEXP        .DE $0013      ;FPOP EXPONENT
0190  WORK0         .DE $0014      ;WORK AREA
0200  IOLSW         .DE $001F      ;I/O WORK AREA LS BYTE
0210  IOSTR         .DE $0023      ;I/O STORAGE
0220  IOSTR3        .DE $0026      ;I/O STORAGE
0230  IOEXPD        .DE $0027      ;I/O EXPONENT STORAGE
0240  ROTATL        .DE $2000      ;ROTATE LEFT
0241  COMPLM        .DE $2018      ;COMPLEMENT
0250  FPMULT        .DE $2110      ;FLOATING POINT MULTIPLY
0260  ;
0270  ;CLEAR A SECTION OF MEMORY
0280  CLRMEM        LDA #$00       ;SET UP ZERO VALUE
0290                TAY  ;INITIALIZE INDEX POINTER
0300  CLRM1         STA (TOPNT),Y          ;CLEAR MEMORY LOCATION
0310                INY  ;ADVANCE INDEX POINTER
0320                DEX  ;DECREMENT COUNTER
0330                BNE CLRM1      ;NOT ZERO,CONTINUE CLEARING
0340                RTS  ;RETURN
0350  ;
0360  ;TRANSFER A SECTION OF MEMORY
0370  MOVIND        LDY #$00       ;INITIALIZE INDEX POINTER
0380  MOVIN1        LDA (FMPNT),Y          ;FETCH BYTE TO TRANSFER
0390                STA (TOPNT),Y          ;STORE BYTE IN NEW LOCATION
0400                INY  ;ADVANCE INDEX POINTER
0410                DEX  ;DECREMENT BYTE COUNTER
0420                BNE MOVIN1     ;NOT ZERO, CONTINUE
0430                RTS  ;RETURN
0440  ;
0450  ;MULTIPLE PRECISION ADDITION
0460  ADDER         CLC  ;CLEAR CARRY FLAG
0470  ADDR1         LDA (TOPNT),Y          ;FETCH BYTE FROM ONE VALUE
0480                ADC (FMPNT),Y          ;ADD BYTE OF OTHER VALUE
```

```
0490            STA (TOPNT),Y          ;STORE RESULT
0500            INY  ;INCREMENT INDEX POINTER
0510            DEX  ;DECREMENT COUNTER
0520            BNE ADDR1     ;NOT ZERO, CONTINUE ADDITION
0530            RTS  ;RETURN
0540    ;
0830    ;MULTIPLY FPACC BY TEN
0840    FPX10   LDA #$04
0850            STA FOPEXP    ;LOAD FPOP WITH A VALUE OF TEN
0860            LDA #$50      ; BY SETTING THE EXPONENT TO FOUR
0870            STA FOPMSW    ;AND THE MANTISSA TO $50,$00,$00
0880            LDA #$00
0890            STA FOPNSW
0900            STA FOPLSW
0910            JSR FPMULT    ;MULTIPLY FPACC BY FPOP
0920            DEC IOEXPD    ;DECREMENT DECIMAL EXPONENT
0930            RTS  ;RETURN TO TEST FOR COMPLETION
0940    ;
0950    ;MULTIPLY FPACC BY 0.1
0960    FPD10   LDA #$FD      ;PLACE 0.1 IN FPOP BY
0970            STA FOPEXP    ; SETTING FPOP EXPONENT TO -3
0980            LDA #$66      ;AND LOADING MANTISSA
0990            STA FOPMSW    ;WITH $66,$66,$67
1000            STA FOPNSW
1010            LDA #$67
1020            STA FOPLSW
1030            JSR FPMULT    ;MULTIPLY FPACC BY FPOP
1040            INC IOEXPD    ;INCREMENT DECIMAL EXPONENT
1050            RTS  ;RETURN
1060    ;
1070    DECBIN  LDA #$00
1080            STA IOSTR3    ;CLEAR MS BYTE+1 OF RESULT
1090            LDX #IOLSW    ;SET POINTER TO I/O WORK AREA
1100            STX TOPNT     ;STORE IN TOPNT
1110            LDX #IOSTR    ;SET POINTER TO I/O STORAGE
1120            STX FMPNT     ;STORE IN FMPNT
1130            LDX #$04      ;SET PRECISION COUNTER
1140            JSR MOVIND    ;MOVE I/O STORAGE TO WORK AREA
1150            LDX #IOSTR    ;SET POINTER TO ORIGINAL VALUE
1160            LDY #$04      ;SET PRECISION COUNTER
1170            JSR ROTATL    ;START X 10 ROUTINE (TOTAL=X2)
1180            LDX #IOSTR    ;RESET POINTER
1190            LDY #$04      ;SET PRECISION COUNTER
1200            JSR ROTATL    ;MULTIPLY BY TWO AGAIN (TOTAL=X4)
1210            LDX #IOLSW    ;SET POINTER TO I/O WORK AREA
1220            STX FMPNT     ;STOPE IN FMPNT
1230            LDX #IOSTR    ;SET POINTER TO I/O STORAGE
1240            STX TOPNT     ;STORE IN TOPNT
1250            LDX #$04      ;SET PRECISION COUNTER
1260            JSR ADDER     ;ADD ORIGINAL TO ROTATED (TOTAL=X5)
1270            LDX #IOSTR    ;RESET POINTER
1280            LDY #$04      ;SET PRECISION COUNTER
1290            JMP ROTATL    ;X2 AGAIN (TOTAL=X10) AND RETURN
1300            .EN
```

Module: Floating Point Multiply

```
>LOAD FPMUL

>PR
 0010  ;FLOATING POINT MULTIPLY
 0020               .BA $2110
 0030               .OS
 0050  FMPNT        .DE $0000     ;FROM POINTER
 0060  TOPNT        .DE $0002     ;TO POINTER
 0070  CNTR         .DE $0004     ;COUNTER STORAGE
 0080  SIGNS        .DE $0006     ;SIGNS INDICATOR
 0090  FPLSWE       .DE $0007     ;FPACC EXTENSION
 0100  FPLSW        .DE $0008     ;FPACC LEAST SIGNIFICANT BYTE
 0110  FPNSW        .DE $0009     ;FPACC NEXT SIGNIFICANT BYTE
 0120  FPMSW        .DE $000A     ;FPACC MOST SIGNIFICANT BYTE
 0130  FPACCE       .DE $000B     ;FPACC EXPONENT
 0140  MCAND0       .DE $000C     ;MULTIPLICATION WORK AREA
 0150  MCAND1       .DE $000D     ;MUTIPLICATION WORK AREA
 0160  FOPLSW       .DE $0010     ;FPOP LEAST SIGNIFICANT BYTE
 0170  FOPMSW       .DE $0012     ;FPOP MOST SIGNIFICANT BYTE
 0180  FOPEXP       .DE $0013     ;FPOP EXPONENT
 0190  WORK0        .DE $0014     ;WORK AREA
 0200  WORK1        .DE $0015     ;WORK AREA
 0210  WORK3        .DE $0017     ;WORK AREA
 0220  WORK6        .DE $001A     ;WORK AREA
 0230  PAGE0        .DE $0000
 0250  ROTATR       .DE $200C     ;ROTATE RIGHT
 0260  ADDER        .DE $2045     ;ADDITION ROUTINE
 0270  MOVIND       .DE $203A     ;ROUTINE TO MOVE BYTES

 0280  COMPLM       .DE $2018     ;COMPLEMENT BYTES

 0290  CLRMEM       .DE $2030     ;CLEAR AN AREA OF MEMORY
 0300  FPNORM       .DE $21FA     ;FLOATING POINT NORMALIZATION
 0310  FPMULT       JSR CKSIGN    ;SET UP AND CHECK SIGN OF MANTISSAS
 0320               LDA FOPEXP    ;GET FPOP EXPONENT
 0330               CLC  ;ADD FPACC EXPONENT
 0340               ADC FPACCE    ;TO FPOP EXPONENT
 0350               STA FPACCE    ;SAVE IN FPACC EXPONENT
 0360               INC FPACCE    ;ADD ONE FOR ALGORITHM COMPENSATION
 0370  SETMCT       LDA #$17      ;SET BIT COUNTER
 0380               STA CNTR      ;STORE BIT COUNTER
 0390  MULTIP       LDX #FPMSW    ;SET POINTER TO FPACC MS BYTE
 0400               LDY #$3       ;SET PRECISION COUNTER
 0410               JSR ROTATR    ;ROTATE FPACC RIGHT
 0420               BCC NADOPP    ;CARRY=0,DON'T ADD PARTIAL PRODUCT
 0430  ADOPP        LDX #MCAND1   ;POINTER TO LS BYTE OF MULTIPLICAND
 0440               STX FMPNT     ;STORE POINTER
 0450               LDX #WORK1    ;POINTER TO LS BYTE OF PARTIAL PRODUCT
 0460               STX TOPNT     ;STORE POINTER
 0470               LDX #$6       ;SET PRECISION COUNTER
 0480               JSR ADDER     ;ADD MULTIPLICAND TO PARTIAL PRODUCT
```

```
0490 NADOPP     LDX #WORK6    ;SET POINTER TO MS BYTE OF PARTIAL
0500 ; PRODUCT
0510            LDY #$6       ;SET PRECISION COUNTER
0520            JSR ROTATR    ;ROTATE PARTIAL PRODUCT RIGHT
0530            DEC CNTR      ;DECREMENT BIT COUNTER
0540            BNE MULTIP    ;NOT ZERO, CONTINUE MULTIPLYING
0550            LDX #WORK6    ;ELSE, SET POINTER TO PARTIAL PRODUCT
0560            LDY #$6       ;SET PRECISION COUNTER
0570            JSR ROTATR    ;MAKE ROOM FOR POSSIBLE ROUNDING
0580            LDX WORK3     ;SET POINTER TO 24TH BIT OF
0590 ; PARTIAL PRODUCT
0600            LDA PAGE0,X   ;FETCH LS BYTE-1 OF RESULT
0610            ROL A         ;ROTATE 24TH BIT TO SIGN
0620            BPL PREXFR    ;IF 24TH BIT=0, BRANCH AHEAD
0630            CLC  ;CLEAR CARRY FOR ADDITIOON
0640            LDY #$3       ;SET PRECISION COUNTER
0650            LDA #$40      ;ADD ONE TO 23RD BIT OF PARTAIL-PRODUCT
0660            ADC PAGE0,X   ;TO ROUND OFF RESULT
0670            STA WORK3     ;STORE SUM IN MEMORY
0680 CROUND     LDA #$0       ;CLEAR A WITHOUT CHANGING CARRY
0690            ADC PAGE0,X   ;ADD WITH CARRY TO PROPOGATE
0700            STA PAGE0,X   ;STORE IN PARTIAL-PRODUCT
0710            INX  ;INCREMENT INDEX POINTER
0720            DEY  ;DCREMENT COUNTER
0730            BNE CROUND    ;NOT ZERO, ADD NEXT BYTE
0740 PREXFR     LDX #FPLSWE   ;SET POINTER TO FPACC LSW-1
0750            STX TOPNT     ;STORE IN TOPNT
0760            LDX #WORK3    ;SET POINTER TO PARTIAL PRODUCT
0770 ; LSW-1
0780            STX FMPNT     ;STORE IN FMPNT
0790            LDX #$4       ;SET PRECISION COUNTER
0800 EXMLDV     JSR MOVIND    ;MOVE PARTIAL PRODUCT TO FPACC
0810            JSR FPNORM    ;NORMALIZE RESULT
0820            LDA SIGNS     ;GET SIGN STORAGE
0830            BNE MULTEX    ;IF NOT ZERO, SIGN IS POSITIVE
0840            LDX #FPLSW    ;ELSE,SET POINTER TO FPACC LS BYTE
0850            LDY #$3       ;SET PRECISION COUNTER
0860            JSR COMPLM    ;COMPLEMENT RESULT
0870 MULTEX     RTS  ;EXIT FPMUL1
0880 CKSIGN     LDA #$0       ;SET PAGE PORTION OF POINTERS
0890            STA TOPNT+1   ;STORE IN TOPNT
0900            STA FMPNT+1   ;STORE IN FMPNT
0910            LDA #WORK0    ;SET POINTER TO WORK AREA
0920            STA TOPNT     ;STORE IN TOPNT
0930            LDX #$8       ;SET PRECISION COUNTER
0940            JSR CLRMEM    ;CLEAR WORK AREA
0950            LDA #MCAND0   ;SET POINTER TO MULTIPLICAND STORAGE
0960            STA TOPNT     ;STORE IN TOPNT
0970            LDX #$4       ;SET PRECISION COUNTER
0980            JSR CLRMEM    ;CLEAR MULTIPLICAND STORAGE
0990            LDA #$1       ;INITIALIZE SIGN INDICATOR
1000            STA SIGNS     ; BY STORING ONE IN SIGNS
1010            LDA FPMSW     ;FETCH FPACC MS BYTE
1020            BPL OPSGNT    ;POSITIVE, CHECK FPOP
```

```
NEGFPA     DEC SIGNS     ;IF NEGATIVE, DECREMENT SIGNS
           LDX #FPLSW    ;SET POINTER TO FPACC LS BYTE
           LDY #$3       ;SET PRECISION COUNTER
           JSR COMPLM    ;MAKE POSITIVE FOR MULTIPLICATION
OPSGNT     LDA FOPMSW    ;IS FPOP NEGATIVE?
           BMI NEGOP     ;YES, COMPLEMENT VALUE
           RTS  ;ELSE, RETURN
NEGOP      DEC SIGNS     ;DECREMENT SIGNS INDICATOR
           LDX #FOPLSW   ;SET POINTER TO FPOP LS BYTE
           LDY #$3       ;SET PRECISION COUNTER
           JMP COMPLM    ;COMPLEMENT FPOP AND RETURN
           .EN
```

Module: Convert to Floating Point

```
>LOAD CONVE

>PR
0010 ;CONVERT
0020 ;  THIS CONVERTS A THREE BYTE NUMBER TO FLOATING POINT
0030 ;FORMAT.  THE NUMBER TO BE CONVERTED IS IN NUM1, 2, AND 3
0040 ;WITH NUM1 THE LSB.  THE RESULT IS IN THE FPLSW, FPNSW, FPACCE.
0050                .BA $21E0
0060                .OS
0070 TSIGN          .DE $0005     ;SIGN INDICATOR
0080 FPLSW          .DE $0008     ;FPACC LEAST SIG BYTE
0090 FPNSW          .DE $0009     ;FPACC NEXT SIG BYTE
0100 FPMSW          .DE $000A     ;FPACC MOST SIG BYTE
0110 FPACCE         .DE $000B     ;FPACC EXPONENT
0120 NUM1           .DS 1         ;LO BYTE OF NUMBER TO BE CONVERTED
0130 NUM2           .DS 1         ;MIDDLE BYTE OF NUMBER TO BE CONVERTED
0140 NUM3           .DS 1         ;HIGH BYTE OF NUMBER TO BE CONVERTED
0150 PAGE0          .DE $0000
0160 FPLSWE         .DE $0007
0170 COMPLM         .DE $2018     ;COMPLEMENT SUBROUTINE
0180 ROTATL         .DE $2000     ;ROTATE LEFT SUBROUTINE
0190 ROTATR         .DE $200C     ;ROTATE RIGHT SUBROUTINE
0200 ;
0210 CONVER         LDA NUM1      ;LOAD THE NUMBER TO
0220                STA FPLSW     ; BE CONVERTED INTO
0230                LDA NUM2      ; THE FLOATING POINT
0240                STA FPNSW     ; ACCUMULATOR
0250                LDA NUM3
0260                STA FPMSW
0270                LDA #23
0280                STA FPACCE
0290 ;
0300 FPNORM         LDX #TSIGN    ;SET POINTER TO SIGN REGISTER
0310                LDA FPMSW     ;FETCH FPACC MS BYTE
0320                BMI ACCMIN    ;IF NEGATIVE, BRANCH
0330                LDY #$00      ;IF POS, CLEAR SIGN REGISTER
0340                TYA
0350                STA PAGE0,X   ; BY STORING ZERO
0360                JMP ACZERT    ;THEN TEST IF FPACC=0
0370 ACCMIN         STA PAGE0,X   ;SET SUGN INDICATOR IF MINUS
0380                LDY #$04      ;SET PRECISION COUNTER
0390                LDX #FPLSWE   ;SET POINTER TO FPACC LS BYTE-1
0400                JSR COMPLM    ;TWO'S COMPLEMENT FPACC
0410 ACZERT         LDX #FPMSW    ;SET POINTER TO FPACC MS BYTE
0420                LDY #$04      ;SET PRECISION COUNTER
0430 LOOK0          LDA PAGE0,X   ;SEE IF FPACC=0
0440                BNE ACNONZ    ;BRANCH IF NONZERO
0450                DEX  ;DECREMENT INDEX POINTER
0460                DEY  ;DECREMENT BYTE COUNTER
0470                BNE LOOK0     ;IF COUNTER NOT ZERO, CONTINUE
```

```
0480             STY FPACCE   ;FPACC=0, CLEAR EXPONENT TOO
0490  NORMEX     RTS  ;EXIT NORMALIZATION ROUTINE
0500  ACNONZ     LDX #FPLSWE  ;SET POINTER TO FPACC LS BYTE-1
0510             LDY #$04     ;SET PRECISION COUNTER
0520             JSR ROTATL   ;ROTATE FPACC LEFT
0530             LDA PAGE0,X  ;SEE IF ONE IN MS BIT
0540             BMI ACCSET   ;IF MINUS, PROPERLY JUSTIFIED
0550             DEC FPACCE   ;IF POSITIVE, DECREMENT FPACC EXPONENT
0560             JMP ACNONZ   ;CONTINUE ROTATING
0570  ACCSET     LDX #FPMSW   ;SET POINTER TO FPACC MS BYTE
0580             LDY #$03     ;SET PRECISION COUNTER
0590             JSR ROTATR   ;COMPENSATING ROTATE RIGHT FPACC
0600             LDA TSIGN    ;IS ORIGINAL SIGN POSITIVE
0610             BEQ NORMEX   ;YES, SIMPLY RETURN
0620             LDY #$03     ;WITH POINTER AT LS BYTE
0630  ;SET PRECISION COUNTER
0640             JMP COMPLM   ;RESTORE FPACC TO NEG AND RETURN
0650             .EN
```

Module: Floating Point Divide

```
>LOAD FPDIV

>PR
 0010  ;FLOATING POINT DIVIDE
 0020  ; DIVIDENT=FPACC
 0030  ; DIVISOR=FPOP
 0040  ; RESULT=FPACC
 0050                .BA $2260
 0060                .OS
 0080  OUTCHR        .DE $8A47     ;OUTPUT A CHARACTER
 0090  FMPNT         .DE $0000     ;FROM POINTER
 0100  TOPNT         .DE $0002     ;TO POINTER
 0110  CNTR          .DE $0004     ;COUNTER STORAGE
 0120  SIGNS         .DE $0006     ;SIGN INDICATOR
 0130  FPLSWE        .DE $0007     ;FPACC EXTENSION
 0140  FPLSW         .DE $0008     ;FPACC LEAST SIG BYTE
 0150  FPNSW         .DE $0009     ;FPACC NEXT SIG BYTE
 0160  FPMSW         .DE $000A     ;FPACC MOST SIG BYTE
 0170  FPACCE        .DE $000B     ;FPACC EXPONENT
 0180  FOLSWE        .DE $000F     ;FPOP EXTENSION
 0190  FOPLSW        .DE $0010     ;FPOP LEAST SIG BYTE
 0200  FOPNSW        .DE $0011     ;FPOP NEXT SIG BYTE
 0210  FOPMSW        .DE $0012     ;FPOP MOST SIG BYTE
 0220  FOPEXP        .DE $0013     ;FPOP EXPONENT
 0230  WORK0         .DE $0014     ;WORK AREA
 0240  WORK1         .DE $0015
 0250  WORK2         .DE $0016
 0260  WORK3         .DE $0017
 0270  WORK4         .DE $0018
 0280  WORK5         .DE $0019
 0290  WORK6         .DE $001A
 0300  CKSIGN        .DE $218F     ;CHECK SIGN
 0310  MOVIND        .DE $203A     ;MOVE BYTES
 0320  ROTL          .DE $2001     ;ROTATE LEFT
 0330  ROTATL        .DE $2000     ;ROTATE LEFT
 0340  ROTATR        .DE $200C     ;ROTATE RIGHT
 0341  COMPLM        .DE $2018     ;TWO'S COMPLEMENT BYTES
 0350  FPNORM        .DE $21FA     ;FLOATING POINT NORMALIZTION
 0360  ;
 0370  FPDIV         JSR CKSIGN    ;CLEAR WORK AREA AND SET SIGNS
 0380                LDA FPMSW     ;CHECK FOR DIVIDE BY ZERO
 0390                BEQ DERROR    ;DIVISOR=0, DIVIDE BY ZERO ERROR
 0400  SUBEXP        LDA FOPEXP    ;GET DIVIDEND EXPONENT
 0410                SEC  ;SET CARRY FOR SUBTRACTION
 0420                SBC FPACCE    ;SUBTRACT DIVISOR EXPONENT
 0430                STA FPACCE    ;STORE RESULT IN FPACC EXPONENT
 0440                INC FPACCE    ;COMPENSATE FOR DIVIDE ALGORITHM
 0450  SETDCT        LDA #$17      ;SET BIT COUNTER STORAGE
 0460                STA CNTR      ; TO 17 HEXADECIMAL
 0470  DIVIDE        JSR SETSUB    ;SUBTRACT DIVISOR FROM DIVIDEND
```

```
0480            BMI NOGO      ;IF RESULT MINUS, ROTATE ZERO
0490  ; IN QUOTIENT
0500            LDX #FOPLSW   ;SET POINTER TO DIVIDEND
0510            STX TOPNT     ;STORE IN TOPNT
0520            LDX #WORK0    ;SET POINTER TO QUOTIENT
0530            STX FMPNT     ;STORE IN FMPNT
0540            LDX #$03      ;SET PRECISION COUNTER
0550            JSR MOVIND    ;MOVE QUOTIENT TO DIVIDEND
0560            SEC   ;SET CARRY FOR POSITIVE RESULTS
0570            JMP QUOROT    ;ROTATE INTO QUOTIENT
0580  DERROR    LDA #$BF      ;SET ASCII FOR ?
0590            JSR OUTCHR
0600            RTS
0610  NOGO      CLC   ;NEGATIVE RESULT, CLEAR CARRY
0620  QUOROT    LDX #WORK4    ;SET POINTER TO QUOTIENT LS BYTE
0630            LDY #$3       ;SET PRECISION COUNT
0640            JSR ROTL      ;ROTATE CARRY INTO LSB OF QUOTIENT
0650            LDX #FOPLSW   ;SET POINTER TO DIVIDEND LS BYTE
0660            LDY #$3       ;SET PRECISION COUNTER
0670            JSR ROTATL    ;ROTATE DIVIDEND LEFT
0680            DEC CNTR      ;DECREMENT BIT COUNTER
0690            BNE DIVIDE    ;IF NOT ZERO, CONTINUE
0700            JSR SETSUB    ;DO ONE MORE FOR ROUNDING
0710            BMI DVEXIT    ;IF MINUS, NO ROUNDING
0720            LDA #$1       ;IF 0 OR +, ADD 1 TO 23RD BIT
0730            CLC   ;CLEAR CARRY FOR ADDITION
0740            ADC WORK4     ;ROUND LS BYTE OF QUOTIENT
0750            STA WORK4     ;RESTORE BYTE IN WORK AREA
0760            LDA #$0       ;CLEAR A, NOT THE CARRY
0770            ADC WORK5     ;ADD CARRY TO 2ND BYTE OF QOUTIENT
0780            STA WORK5     ;STORE RESULT
0790            LDA #$0       ;CLEAR A, NOT THE CARRY
0800            ADC WORK6     ;ADD CARRY TO MS BYTE
0810  ; OF QUOTIENT
0820            STA WORK6     ;STORE RESULT
0830            BPL DVEXIT    ;IF MSB=0, EXIT
0840            LDX #WORK6    ;ELSE PREPARE TO ROTATE RIGHT
0850            LDY #$3       ;SET PRECISION COUNTER
0860            JSR ROTATR    ;CLEAR SIGN BIT COUNTER
0870            INC FPACCE    ;COMPENSATE EXP FOR ROTATE
0880  DVEXIT    LDX #FPLSWE   ;SET POINTER TO FPACC
0890            STX TOPNT     ;STORE IN TOPNT
0900            LDX #WORK3    ;SET POINTER TO QUOTIENT
0910            STX FMPNT     ;STORE IN FMPNT
0920            LDX #$4       ;SET PRECISION COUNTER
0930            JMP EXMLDV    ;MOVE QOTIENT TO FPACC
0940  SETSUB    LDX #WORK0    ;SET POINTER TO WORK AREA
0950            STX TOPNT     ;STORE IN TOPNT
0960            LDX #FPLSW    ;SET POINTER TO FPACC
0970            STX FMPNT     ;STORE IN FMPNT
0980            LDX #$3       ;SET PRECISION COUNTER
0990            JSR MOVIND    ;MOVE FPACC TO WORK AREA
1000            LDX #WORK0    ;PREPARE FOR SUBTRACTION
  10            STX TOPNT     ;STORE POINTER TO DIVISOR
1020            LDX #FOPLSW   ;SET POINTER TO FPOP LS BYTE-1
```

```
                STX FMPNT    ;STORE POINTER TO DIVIDEND
                LDY #$0      ;INITIALIZE INDEX POINTER
                LDX #3       ;SET PRECISION COUNTER
                SEC  ;SET CARRY FOR SUBTRACTION
SUBR1           LDA (FMPNT),Y         ;FETCH FPOP BYTE (DIVIDEND)
                SBC (TOPNT),Y         ;SUBTRACT FPACC BYTE (DIVISOR)
                STA (TOPNT),Y         ;STORE IN PLACE OF DIVISOR
                INY  ;ADVANCE INDEX POINTER
                DEX  ;DECREMENT PRECISION COUNTER
                BNE SUBR1    ;NOT ZERO, CONTINUE SUBTR
                LDA WORK2    ;SET SIGN BIT RESULT IN N FLAG
                RTS  ;RETURN WITH FLAG CONDITIONED
EXMLDV          JSR MOVIND   ;MOVE PARTIAL PRODUCT TO FPACC
                JSR FPNORM   ;NORMALIZE RESULT
                LDA SIGNS    ;GET SIGN STORAGE
                BNE MULTEX   ;IF NOT ZERO, SIGN IS POSITIVE
                LDX #FPLSW   ;ELSE,SET POINTER TO FPACC LS BYTE
                LDY #$3      ;SET PRECISION COUNTER
                JSR COMPLM   ;COMPLEMENT RESULT
MULTEX          RTS  ;EXIT FPDIV
                .EN
```

Module: Floating Point Output

```
>LOAD FPOUT

>PR
0010 ;FLOATING POINT OUTPUT ROUTINE
0020 ;  THIS ROUTINE PRINTS OUT A FLOATING POINT BINARY NUMBER
0030 ;IN DECIMAL.
0040                .BA $2340
0050                .OS
0070 IOEXPD         .DE $0027     ;I/O EXPONENT STORAGE
0080 FPMSW          .DE $000A     ;FPACC MOST SIGNIFICANT BYTE
0090 FPLSW          .DE $0008     ;FPACC LEAST SIGNIFICANT BYTE
0100 FMPNT          .DE $0000     ;FROM POINTER
0110 FPACCE         .DE $000B     ;FPACC EXPONENT
0120 CNTR           .DE $0004     ;COUNTER STORAGE
0130 TOPNT          .DE $0002     ;TO POINTER
0140 IOSTR          .DE $0023     ;I/O STORAGE
0150 IOSTR1         .DE $0024     ;I/O STORAGE
0160 IOSTR2         .DE $0025     ;I/O STORAGE
0170 IOSTR3         .DE $0026     ;I/O STORAGE
0180 COMPLM         .DE $2018     ;COMPLEMENT ROUTINE
0190 ROTATL         .DE $2000     ;ROTATE LEFT
0200 ROTATR         .DE $200C     ;ROTATE RIGHT
0210 FPX10          .DE $2051     ;MULTIPLY FPACC BY 10
0220 FPD10          .DE $206A     ;MULTIPLY FPACC BY 0.1
0230 MOVIND         .DE $203A     ;TRANSFER A SECTION OF MEMORY
0240 DECBIN         .DE $2083
0250 OUTCHR         .DE $8A47     ;OUTPUT A CHARACTER
0260 FPOUT          LDA #$0
0270                STA IOEXPD    ;CLEAR DECIMAL EXPONENT STORAGE
0280                LDA FPMSW     ;IS VALUE TO BE OUTPUT NEG?
0290                BMI OUTNEG    ;YES,MAKE POS AND OUTPUT '-'
0300                LDA #$AB      ;ELSE,SET ASCII CODE FOR '+'
0310                BNE AHEAD1    ;GO DISPLAY + SIGN
0320 OUTNEG         LDX #FPLSW    ;SET POINTER TO LS BYTE OF FPACC
0330                LDY #$3       ;SET PRECISION COUNTER
0340                JSR COMPLM    ;MAKE FPACC POSITIVE
0350                LDA #$AD      ;SET ASCII CODE FOR '-'
0360 AHEAD1         JSR OUTCHR    ;OUTPUT SIGN OF RESULT
0370                LDA #$B0      ;SET UP ASCII ZERO
0380                JSR OUTCHR    ;OUTPUT ZERO TO DISPLAY
0390                LDA #$AE      ;SET UP ASCII DECIMAL POINT
0400                JSR OUTCHR    ;OUTPUT DECIMAL POINT
0410                DEC FPACCE    ;DECREMENT FPACC EXPONENT
0420 DECEXT         BPL DECEXD    ;IF COMPENSATED, EXP>=0
0430                LDA #$4       ;EXPONENT NEG,ADD FOUR TO FPACCE
0440                CLC  ;CLEAR CARRY FOR ADDITION
0450                ADC FPACCE    ;ADD FOUR TO FPACC EXPONENT
0460                BPL DECOUT    ;IF EXP>=0, OUTPUT MANTISSA
0470                JSR FPX10     ;ELSE MULTIPLY MANISSA BY TEN
0480 DECREP         LDA FPACCE    ;GET EXPONENT
```

```
0490             JMP DECEXT   ;REPEAT TEST FOR >=0
0500  DECEXD     JSR FPD10    ;MULTIPLY FPACC BY 0.1
0510             JMP DECREP   ;CHECK STATUS OF FPACC EXPONENT
0520  DECOUT     LDX #IOSTR   ;SET UP FOR MOVE OPERATION
0530             STX TOPNT    ;SET TOPNT TO WORKING REGISTER
0540             LDX #FPLSW   ;SET POINTER TO FPACC LS BYTE
0550             STX FMPNT    ;STORE IN FMPNT
0560             LDX #$3      ;SET PRECISION COUNTER
0570             JSR MOVIND   ;MOVE FPACC TO OUTPUT REGISTERS
0580             LDA #$0
0590             STA IOSTR3   ;CLEAR OUTPUT REGISTER MS BYTE+1
0600             LDX #IOSTR   ;SET POINTER TO OUTPUT LS BY
0610             LDY #$3      ;SET PRECISION COUNTER
0620             JSR ROTATL   ;ROTATE TO COMPENSATE FOR SIGN BIT
0630             JSR DECBIN   ;OUTPUT REGISTER X 10, OVERFLOW
0640  ;IN MS BYTE +1
0650  COMPEN     INC FPACCE   ;INCREMENT FPACC EXPONENT
0660             BEQ OUTDIG   ;OUTPUT A DIGIT WHEN COMPENSATION DONE
0670             LDX #IOSTR3  ;ELSE ROTATE RIGHT TO COMPENSATE
0680             LDY #$4      ;FOR ANY REMAINDER IN BINARY EXP
0690             JSR ROTATR   ;PERFORM ROTATE RIGHT OPERATION
0700             JMP COMPEN   ;REPAET LOOP UNTIL EXP=0
0710  OUTDIG     LDA #$7      ;SET DIGIT COUNTER TO SEVEN
0720             STA CNTR     ; FOR OUTPUT OPERATION
0730             LDA IOSTR3   ;FETCH BCD, SEE IF FIRST DIGIT = 0
0740             BEQ ZERODG   ;YES,CHECK REMAINDER OF DIGITS
0750  OUTDGS     LDA IOSTR3   ;GET BCD FROM OUTPUT REGISTER
0760             ORA #$B0     ;FORM ASCII CODE FOR NUMBERS
0770             JSR OUTCHR   ; AND OUTPUT DIGIT
0780  DECRDG     DEC CNTR     ;DECREMENT DIGIT COUNTER
0790             BEQ EXPOUT   ;=0,DONE OUTPUT EXPONENT
0800             JSR DECBIN   ;ELSE GET NEXT DIGIT
0810             JMP OUTDGS   ;FORM ASCII AND OUTPUT
0820  ZERODG     DEC IOEXPD   ;DECREMENT EXP FOR SKIPPING DISPLAY
0830             LDA IOSTR2   ;CHECK IF MANTISSA =0
0840             BNE DECRDG   ;IF NOT ZERO, CONTINUE OUTPUT
0850             LDA IOSTR1
0860             BNE DECRDG
0870             LDA IOSTR
0880             BNE DECRDG
0890             LDA #$0      ;MANTISSA ZERO,CLEAR EXPONENT
0900             STA IOEXPD
0910             BEQ DECRDG   ;BEFORE FINISHING DISPLAY
0920  EXPOUT     LDA #$C5     ;SET UP ASCII CODE FOR E
0930             JSR OUTCHR   ;DISPLAY E FOR EXPONENT
0940             LDA IOEXPD   ;TEST IF NEGATIVE
0950             BMI EXOUTN   ;YES,DISPLAY '-' AND NEGATE
0960             LDA #$AB     ;NO,SET ASCII CODE FOR '+'
0970             JMP AHEAD2   ;DISPLAY EXPONENT VALUE
0980  EXOUTN     EOR #$FF     ;TWO'S COMPLEMENT EXPONENT
0990             STA IOEXPD   ;TO MAKE NEG VALUE POS
1000             INC IOEXPD   ;FOR OUTPUT OF EXPONENT VALUE
1010             LDA #$AD     ;SET ASCII CODE FOR '-'
1020  AHEAD2     JSR OUTCHR   ;OUTPUT SIGN OF EXPONENT
1030             LDY #$0      ;CLEAR TEN'S COUNTER
```

```
1040          LDA IDEXPD   ;FETCH EXPONENT
1050   SUB12  SEC  ;SET CARRY FOR SUBTRACTION
1060          SBC #$0A     ;SUBTRACT TEN'S FROM EXPONENT
1070          BMI TOMUCH   ;IF MINUS,READY FOR OUTPUT
1080          STA IDEXPD   ;RETORE POSITVE RESULT
1090          INY  ;ADVANCE TEN'S COUNTER
1100          JMP SUB12    ;CONTINUE SUBTRACTION
1110   TOMUCH TYA  ;PUT MS DIGIT INTO A
1120          ORA #$B0     ;FORM ASCII CODE
1130          JSR OUTCHR   ;OUTPUT TEN'S DIGIT TO DISPLAY
1140          LDA IDEXPD   ;FETCH UNIT'S DIGIT
1150          ORA #$B0     ;FORM ASCII CODE
1160          JSR OUTCHR   ;OUTPUT DIGIT
1170          RTS
1180          .EN
```

. Module: Convert, Divide and Output Floating Point.

```
>LOAD PRINT

>PP
0010                .BA $2430
0020                .OS
0030 ;THIS MODULE WILL CONVERT A THREE BYTE DIVISOR AND DIVIDEND
0040 ;TO FLOATING POINT FORMAT, DO A FLOATING POINT DIVIDE, AND
0050 ;OUTPUT THE RESULT IN DECIMAL FLOATING POINT FORMAT.
0060 DIVIS1         .DS 1           ;LO BYTE OF DIVISOR
0070 DIVIS2         .DS 1           ;MIDDLE BYTE OF DIVISOR
0080 DIVIS3         .DS 1           ;HIGH BYTE OF DIVISOR
0090 DVDND1         .DS 1           ;LO BYTE OF DIVIDEND
0100 DVDND2         .DS 1           ;MIDDLE BYTE OF DIVIDEND
0110 DVDND3         .DS 1           ;HIGH BYTE OF DIVIDEND
0120 CONVE          .DE $21E3       ;CONVERT TO FLOATING POINT
0130 FPDIV          .DE $2260       ;FLOATING POINT DIVISION
0140 FPOUT          .DE $2340       ;OUTPUT FP IN DECIMAL
0150 FPLSW          .DE $0008       ;FPACC LEAST SIGNIFICANT BYTE
0160 FPNSW          .DE $0009       ;FPACC NEXT SIGNIFICANT BYTE
0170 FPMSW          .DE $000A       ;FPACC MOST SIGNIFICANT BYTE
0180 FPACCE         .DE $000B       ;FPACC EXPONENT
0190 FOPLSW         .DE $0010       ;FPOP LEAST SIGNIFICANT BYTE
0200 FOPNSW         .DE $0011       ;FPOP NEXT SIGNIFICANT BYTE
  10 FOPMSW         .DE $0012       ;FPOP MOST SIGNIFICANT BYTE
0220 FOPEXP         .DE $0013       ;FPOP EXPONENT
0230 NUM1           .DE $21E0
0240 NUM2           .DE $21E1
0250 NUM3           .DE $21E2
0260 ;
0270 PRINT          TXA
0280                PHA
0290                TYA
0300                PHA
0310                LDA DVDND1      ;PUT DVDND1, 2, AND 3
0320                STA NUM1        ; INTO NUM1, 2, AND 3
0330                LDA DVDND2
0340                STA NUM2
0350                LDA DVDND3
0360                STA NUM3
0370                JSR CONVE       ;CONVERT DIVIDEND TO FP
0380                LDA FPLSW       ;PUT FP RESULT INTO
0390                STA FOPLSW      ; FPOP
0400                LDA FPNSW
0410                STA FOPNSW
0420                LDA FPMSW
0430                STA FOPMSW
0440                LDA FPACCE
0450                STA FOPEXP
 .60                LDA DIVIS1      ;PUT DIVIS1, 2, AND 3
 .70                STA NUM1        ; INTO NUM1, 2 AND 3
```

```
0480        LDA DIVIS2
0490        STA NUM2
0500        LDA DIVIS3
0510        STA NUM3
0520        JSR CONVE     ;CONVERT DIVISOR TO FP
0530        JSR FPDIV     ;FP DIVISION
0540        JSR FPOUT     ;PRINT OUT RESULT OF DIVISION
0550        PLA
0560        TAY
0570        PLA
0580        TAX
0590        RTS
0600        .EN
```

. **Module: Total Mission Parameters.**

```
>LOAD TOVAL

>PR
 0010                   .BA $2700
 0020                   .OS
 0040  TOTFX1           .DS 1           ;LO BYTE OF TOTAL MISSION FIXATIONS
 0050  TOTFX2           .DS 1           ;MID BYTE OF TOTAL MISSION FIXATIONS
 0060  TOTFX3           .DS 1           ;HI BYTE OF TOTAL MISSION FIXATIONS
 0070  TODWL1           .DS 1           ;LO BYTE OF TOTAL MISSION DWELL TIME
 0080  TODWL2           .DS 1           ;MID BYTE OF TOTAL MISSION DWELL TIME
 0090  TODWL3           .DS 1           ;HI BYTE OF TOTAL MISSION DWELL TIME
 0100  TABLE1           .DE $6000       ;LOCATION OF
 0110  TABLE2           .DE $6100       ; FINAL DATA
 0120  TABLE3           .DE $6200       ; TABLE
 0130  TABLE4           .DE $6300
 0140  ;
 0150  ;ADD UP THE TOTAL NUMBER OF FIXATIONS AND THE TOTAL
 0160  ;MISSION DWELL TIME FOR THE DATA MISSION.  THIS IS
 0170  ;DONE FOR INSTS 0-25, NOT FOR BLINK, GLITCH AND
 0180  ;DATA GONE.
 0190  TOVAL            LDA #00         ;INITIALIZE TOTAL FIXATIONS
 0200                   STA TOTFX1      ;AND TOTAL DWELL TIME
 0210                   STA TOTFX2
 0220                   STA TOTFX3
 0230                   STA TODWL1
 0240                   STA TODWL2
 0250                   STA TODWL3
 0260                   LDX #$82        ;LOCATION OF THE LOW BYTE OF THE
 0270                   ; DWELL TIME FOR INST 1
 0280  LOOP1            LDA TABLE1,X            ;ADD THE DWELL TIME
 0290                   CLC  ; FOR AN INSTRUMENT
 0300                   ADC TODWL1    ; TO THE TOTAL
 0310                   STA TODWL1    ; MISSION DWELL TIME
 0320                   INX
 0330                   LDA TABLE1,X
 0340                   ADC TODWL2
 0350                   STA TODWL2
 0360                   INX
 0370                   LDA TABLE1,X
 0380                   ADC TODWL3
 0390                   STA TODWL3
 0400                   INX
 0410                   CLC
 0420                   LDA TABLE1,X            ;ADD THE NUMBER OF
 0430                   ADC TOTFX1    ; FIXATIONS FOR AN
 0440                   STA TOTFX1    ; INSTRUMENT TO THE
 0450                   INX  ; TOTAL MISSION DWELL
 0460                   LDA TABLE1,X            ; TIME
 0470                   ADC TOTFX2
 0480                   STA TOTFX2
```

```
0490            LDA #00
0500            ADC TOTFX3
0510            STA TOTFX3
0520            CPX #$EC      ;ARE AT THE END OF TABLE 1?
0530            BEQ TAB2      ;IF SO, GO TO TABLE2
0540            CLC
0550            TXA  ;TRANSFER X TO ACC
0560            ADC #$1E      ;GO TO NEXT INST IN TABLE 1
0570            TAX
0580            JMP LOOP1
0590  TAB2      LDX #$1C      ;LOOK AT FIRST INST IN TABLE 2
0600  LOOP2     LDA TABLE2,X           ;ADD THE DWELL TIME
0610            CLC  ; FOR AN INSTRUMENT
0620            ADC TODWL1    ; TO THE TOTAL
0630            STA TODWL1    ; MISSION DWELL TIME
0640            INX
0650            LDA TABLE2,X
0660            ADC TODWL2
0670            STA TODWL2
0680            INX
0690            LDA TABLE2,X
0700            ADC TODWL3
0710            STA TODWL3
0720            INX
0730            CLC
0740            LDA TABLE2,X           ;ADD THE NUMBER OF
0750            ADC TOTFX1    ; FIXATIONS FOR AN
0760            STA TOTFX1    ; INSTRUMENT TO THE
0770            INX  ; TOTAL MISSION DWELL
0780            LDA TABLE2,X           ; TIME
0790            ADC TOTFX2
0800            STA TOTFX2
0810            LDA #00
0820            ADC TOTFX3
0830            STA TOTFX3
0840            CPX #$EC      ;ARE AT THE END OF TABLE 2?
0850            BEQ TAB3      ;IF SO, GO TO TABLE2
0860            CLC
0870            TXA  ;TRANSFER X TO ACC
0880            ADC #$1E      ;GO TO NEXT INST IN TABLE 2
0890            TAX
0900            JMP LOOP2
0910  TAB3      LDX #$1C      ;LOOK AT FIRST INST IN TABLE 2
0920  LOOP3     LDA TABLE3,X           ;ADD THE DWELL TIME
0930            CLC  ; FOR AN INSTRUMENT
0940            ADC TODWL1    ; TO THE TOTAL
0950            STA TODWL1    ; MISSION DWELL TIME
0960            INX
0970            LDA TABLE3,X
0980            ADC TODWL2
0990            STA TODWL2
1000            INX
1010            LDA TABLE3,X
1020            ADC TODWL3
1030            STA TODWL3
```

```
                INX
                CLC
                LDA TABLE3,X          ;ADD THE NUMBER OF
                ADC TOTFX1    ; FIXATIONS FOR AN
                STA TOTFX1    ; INSTRUMENT TO THE
                INX  ; TOTAL MISSION DWELL
                LDA TABLE3,X          ; TIME
                ADC TOTFX2
                STA TOTFX2
                LDA #00
                ADC TOTFX3
                STA TOTFX3
                CPX #$EC      ;ARE AT THE END OF TABLE 3?
                BEQ TAB4      ;IF SO, GO TO TABLE4
                CLC
                TXA  ;TRANSFER X TO ACC
                ADC #$1E      ;GO TO NEXT INST IN TABLE 3
                TAX
                JMP LOOP3
TAB4            LDX #$1C      ;LOOK AT FIRST INST IN TABLE 4
LOOP4           LDA TABLE4,X          ;ADD THE DWELL TIME
                CLC  ; FOR AN INSTRUMENT
                ADC TODWL1    ; TO THE TOTAL
                STA TODWL1    ; MISSION DWELL TIME
                INX
                LDA TABLE4,X
                ADC TODWL2
                STA TODWL2
                INX
                LDA TABLE4,X
                ADC TODWL3
                STA TODWL3
                INX
                CLC
                LDA TABLE4,X          ;ADD THE NUMBER OF
                ADC TOTFX1    ; FIXATIONS FOR AN
                STA TOTFX1    ; INSTRUMENT TO THE
                INX  ; TOTAL MISSION DWELL
                LDA TABLE4,X          ; TIME
                ADC TOTFX2
                STA TOTFX2
                LDA #00
                ADC TOTFX3
                STA TOTFX3
                CPX #$EC      ;ARE AT THE END OF TABLE 4?
                BEQ DONE      ;IF SO, DONE
                CLC
                TXA  ;TRANSFER X TO ACC
                ADC #$1E      ;GO TO NEXT INST IN TABLE 4
                TAX
                JMP LOOP4
DONE            RTS
                .EN
```

. **Module: First Table Header.**

```
>LOAD OUTPT

>PR
0010              .BA $2850
0020              .OS
0030  ; THIS ROUTINE PRINTS OUT THE FIRST TABLE
0040  ; COLUMN HEADERS. THE TOTAL NUMBER OF FIXATIONS
0050  ;IN THE DATA MISSION AND THE TOTAL MISSION DWELL TIME.
0060  SPACE       .BY ' '
0070  HEAD1       .BY 'INIT'
0080  HEAD2       .BY 'TOTAL NUMBER'
0090  HEAD3       .BY 'TOTAL DWELL'
0100  HEAD4       .BY 'MEAN DWELL'
0110  HEAD5       .BY 'PROPORTION OF'
0120  HEAD6       .BY 'PROPORTION OF'
0130  HEAD7       .BY 'NUM'
0140  HEAD8       .BY 'OF FIXATIONS'
0150  HEAD9       .BY 'TIME'
0160  HEAD10      .BY 'TIME'
0170  HEAD11      .BY 'TOTAL TIME'
0180  HEAD12      .BY 'TOTAL FIXATION'
0190  UNDER       .BY '_'
0200  NUM1        .DE $21E0      ;LO BYTE OF NUMBER TO BE CONVERTED TO FP
0210  NUM2        .DE $21E1      ;MIDDLE BYTE OF NUMBER TO BE CONVERTED
0220  NUM3        .DE $21E2      ;HI BYTE OF NUMBER TO BE CONVERTED
0230  TOTFX1      .DE $2700      ;LO BYTE OF TOTAL MISSION FIXATIONS
0240  TOTFX2      .DE $2701      ;MIIDLE BYTE OF TOTAL MISSION FIXATIONS
0250  TOTFX3      .DE $2702      ;HI BYTE OF TOTAL MISSION FIXATIONS
0260  TODWL1      .DE $2703      ;LO BYTE OF TOTAL MISSION DWELL TIME
0270  TODWL2      .DE $2704      ;MIDDLE BYTE OF TOTAL MISSION DWELL TIME
0280  TODWL3      .DE $2705      ;HI BYTE OF TOTAL MISSION DWELL TIME
0290  TOTFX       .BY 'TOTAL NUMBER OF FIXATIONS IN THE DATA MISSION= '
0300  TOTDWL      .BY 'TOTAL DWELL TIME IN THE DATA MISSION= '
0310  CRLF        .DE $834D      ;CARRIAGE RETURN AND LINE FEED
0311  CONVE       .DE $21E3      ;CONVERT TO FP
0312  FPOUT       .DE $2340      ;PRINT FP RESULT
0320  OUTCHR      .DE $8A47      ;OUTPUT A CHARACTER
0330  OUTPT1      LDY #47
0340              LDX #00
0350              JSR CRLF       ;GO TO NEXT LINE
0360  LOOPA       LDA TOTFX,X    ;PRINT OUT THE
0370              JSR OUTCHR     ; TOTAL NUMBER OF
0380              INX  ; FIXATIONS IN THE
0390              DEY  ;DATA MISSION
0400              BNE LOOPA
0410              LDA SPACE
0420              JSR OUTCHR
0430              LDA TOTFX1
0440              STA NUM1
0450              LDA TOTFX2
```

```
0460            STA NUM2
  70            LDA TOTFX3
0480            STA NUM3
0490            JSR CONVE     ;CONVERT FIXATIONS TO FP
0500            JSR FPOUT     ;PRINT FLOATING POINT RESULT
0510            JSR CRLF      ;GO TO NEXT LINE
0520            LDY #38
0530            LDX #00
0540 LOOPB      LDA TOTDWL,X           ;PRINT OUT THE
0550            JSR OUTCHR    ; TOTAL MISSION DWELL
0560            INX   ;TIME
0570            DEY
0580            BNE LOOPB
0590            LDA SPACE
0600            JSR OUTCHR
0610            LDA TODWL1
0620            STA NUM1
0630            LDA TODWL2
0640            STA NUM2
0650            LDA TODWL3
0660            STA NUM3
0670            JSR CONVE     ;CONVERT DWELL TIME TO FP
0680            JSR FPOUT     ;OUTPUT THE RESULT
0690            JSR CRLF
0700            JSR CRLF      ;SKIP A LINE
0710            ;
0720 ;PRINT OUT HEADER
 730            JSR CRLF
0740            LDX #00       ;X IS THE POSITION IN HEAD1-12
0750            LDY #4        ;Y IS THE NUM OF CHARS OR SPACES TO PRINT
0760            JSR HOUT      ;PRINT OUT PORTION OF HEADER
0770            LDY #$02
0780            JSR PRSP      ;PRINT OUT 2 SPACES
0790            LDY #12
0800            JSR HOUT      ;PRINT 12 CHARS OF HEADER
0810            LDY #4
0820            JSR PRSP      ;PRINT OUT 4 SPACES
0830            LDY #11
0840            JSR HOUT      ;PRINT 11 CHARS OF HEADER
0850            LDY #4
0860            JSR PRSP      ;PRINT 4 SPACES
0870            LDY #10
0880            JSR HOUT      ;PRINT 10 CHARS OF HEADER
0890            LDY #4
0900            JSR PRSP      ;PRINT 4 SPACES
0910            LDY #13
0920            JSR HOUT      ;PRINT 13 CHARS OF HEADER
0930            LDY #2
0940            JSR PRSP      ;PRINT 2 SPACES
0950            LDY #13
0960            JSR HOUT      ;PRINT 13 CHARS OF HEADER
0970            JSR CRLF      ;GO TO NEXT LINE
0980            LDY #1
 990            JSR PRSP      ;PRINT 1 SPACE
1000            LDY #3
```

```
1010            JSR HOUT      ;PRINT 3 CHARS OF HEADER
  20            LDY #2
1030            JSR PRSP      ;PRINT 2 SPACES
1040            LDY #12
1050            JSR HOUT      ;PRINT 3 CHARS OF HEADER
1060            LDY #7
1070            JSR PRSP      ;PRINT 7 SPACES
1080            LDY #4
1090            JSR HOUT      ;PRINT 4 CHARS OF HEADER
1100            LDY #11
1110            JSR PRSP      ;PRINT 11 SPACES
1120            LDY #4
1130            JSR HOUT      ;PRINT 4 CHARS OF HEADER
1140            LDY #8
1150            JSR PRSP      ;PRINT 8 SPACES
1160            LDY #10
1170            JSR HOUT      ;PRINT 10 CHARS OF HEADER
1180            LDY #3
1190            JSR PRSP      ;PRINT 3 SPACES
1200            LDY #14
1210            JSR HOUT      ;PRINT 14 CHARS OF HEADER
1220            JSR CRLF
1240            LDY #79
1250 LOOP1      LDA UNDER     ;UNDERLINE THE HEADER
1260            JSR OUTCHR
1270            DEY
1280            BNE LOOP1
  90            JSR CRLF      ;TO NEXT LINE
1300            JSR CRLF      ;TO NEXT LINE
1301            RTS
1310 ; SUBROUTINE TO PRINT Y CHARS FROM HEAD
1320 HOUT       LDA HEAD1,X
1330            JSR OUTCHR
1340            INX
1350            DEY
1360            BNE HOUT
1370            RTS
1380 ; SUBROUTINE TP PRINT OUT Y SPACES
1390 PRSP       LDA SPACE
1400            JSR OUTCHR
1410            DEY
1420            BNE PRSP
1430            RTS
1440            .EN
```

. **Module: Output First Table.**

```
>LOAD OUTTB

>PR
                .BA $2A40
                .OS
CRLF            .DE $834D       ;CARRIAGE RETURN AND LINE FEED
OUTCHR          .DE $8A47       ;OUTPUT A CHARACTER
NUMBER          .BY '01 02 03 04 05 06 07 08 09 10 11 12 13 14 '
NUMB1           .BY '15 16 17 18 19 20 21 22 23 24 25 '
SPACE           .BY ' '
GLITCH          .BY 'GLIT'
BLINK           .BY 'BLNK'
DATAGN          .BY 'DAGN'
RESTB           .DE $2BF2
LOTAB           .DE $002D
HITAB           .DE $002E
;
; PRINT OUT THE INFO FOR EACH INST, GLITCH, BLINK,
;AND DATA GONE ROW BY ROW
OUTTB           LDY #4
                LDX #00
LOOP2           LDA GLITCH,X
                JSR OUTCHR
                INX
                DEY
                BNE LOOP2
                LDA SPACE       ;PRINT 1 SPACE
                JSR OUTCHR
                LDX #00
                LDA #00
                STA LOTAB
                LDA #$60
                STA HITAB       ;POINT TO TABLE1
                JSR RESTB       ;PRINT OUT ROW FOR BLINK
                JSR CRLF        ;GO TO NEXT LINE
                LDX #00
                LDY #4
LOOP3           LDA BLINK,X
                JSR OUTCHR      ;PRINT HEADER FOR BLINK
                INX
                DEY
                BNE LOOP3
                LDA SPACE
                JSR OUTCHR      ;PRINT 1 SPACE
                LDX #$22
                LDA #00
                STA LOTAB
                LDA #$60
                STA HITAB
                JSR RESTB       ;PRINT OUT ROW FOR BLINK
```

```
0480          JSR CRLF      ;GO TO NEXT LINE
0490          LDX #00
0500          LDY #4
0510  LOOP4   LDA DATAGN,X
0520          JSR OUTCHR    ;PRINT HEADER FOR DATA GONE
0530          INX
0540          DEY
0550          BNE LOOP4
0560          LDA SPACE
0570          JSR OUTCHR
0580          LDX #$44
0590          LDA #00
0600          STA LOTAB
0610          LDA #$60
0620          STA HITAB     ;POINT AT TABLE1
0630          JSR RESTB     ;PRINT ROW FOR DATA GONE
0640          JSR CRLF      ;GO TO NEXT LINE
0650          LDX #$66
0660          LDY #00
0670  BACK1   JSR FORMAT    ;PRINT HEADER FOR THE INST
0680          LDA #00
0690          STA LOTAB
0700          LDA #$60
0710          STA HITAB     ;POINT AT TABLE1
0720          JSR RESTB     ;PRINT OUT ROW FOR THAT INST
0730          JSR CRLF
0740          CPX #$CC
0750          BEQ NEXT2     ;GO TO TABLE2 IF DONE WITH TABLE1
0760          TXA
0770          CLC
0780          ADC #$22      ;GO TO NEXT INST IN TABLE1
0790          TAX
0800          JMP BACK1
0810  NEXT2   LDX #00
0820  BACK2   JSR FORMAT    ;PRINT HEADER FOR THE INST
0830          LDA #00
0840          STA LOTAB
0850          LDA #$61
0860          STA HITAB     ;POINT TO TABLE2
0870          JSR RESTB     ;PRINT OUT ROW FOR AN INSTRUMENT
0880          JSR CRLF
0890          CPX #$CC
0900          BEQ NEXT3     ;IF DONE WITH TABLE2 GO TO TABLE3
0910          TXA
0920          CLC
0930          ADC #$22      ;GO TO NEXT INST IN TABLE2
0940          TAX
0950          JMP BACK2
0960  NEXT3   LDX #00
0970  BACK3   JSR FORMAT    ;PRINT HEADER FOR THE INST
0980          LDA #00
0990          STA LOTAB
1000          LDA #$62
  10          STA HITAB
1020          JSR RESTB     ;PRINT OUT ROW FOR AN INST
```

```
1030            JSR CRLF
1040            CPX #$CC
1050            BEQ NEXT4     ;GO TO TABLE4 IF DONE WITH TABLE3
1060            TXA
1070            CLC
1080            ADC #$22      ;GO TO NEXT INST IN TABLE3
1090            TAX
1100            JMP BACK3
1110  NEXT4     LDX #00
1120  BACK4     JSR FORMAT    ;PRINT OUT HEADER FOR THE INST
1130            LDA #00
1140            STA LOTAB
1150            LDA #$63
1160            STA HITAB
1170            JSR PRITB     ;PRINT OUT ROW FOR AN INST
1180            JSR CRLF
1190            CPX #$CC
1200            BEQ DONE      ;DONE WITH ALL FOUR TABLES
1210            TXA
1220            CLC
1230            ADC #$22      ;GO TO NEXT INST IN TABLE4
1240            TAX
1250            JMP BACK4
1260  DONE      RTS
1270  ; ROUTINE TO PRINT THE HEADER FOR EACH INST NUMBER
1280  FORMAT    LDA SPACE
1290            JSR OUTCHR
1300            LDA NUMBER,Y
1310            JSR OUTCHR
1320            INY
1330            LDA NUMBER,Y
1340            JSR OUTCHR
1350            INY
1360            LDA NUMBER,Y
1370            JSR OUTCHR
1380            INY
1390            JSR OUTCHR
1400            RTS
1410            .EN
```

. **Module:** Output Row of First Table - called by Output First Table module.

```
>LOAD RESTB

>PP
0010                .BA $2BE0
0020                .OS
0030 NUM1           .DE $21E0    ;NUMBER TO BE CONVERTED TO FLOATING PT
0040 NUM2           .DE $21E1
0050 NUM3           .DE $21E2
0060 PRINT          .DE $2436    ;ROUTINE TO CONVERT TO FP, DIVIDE, AND PRINT
0070 DIVIS1         .DE $2430    ;LO BYTE OF DIVISOR
0080 DIVIS2         .DE $2431    ;MID BYTE OF DIVISOR
0090 DIVIS3         .DE $2432    ;HI BYET OF DIVISOR
0100 DVDND1         .DE $2433    ;LO BYTE OF DIVIDEND
0110 DVDND2         .DE $2434    ;MID BYTE OF DIVIDEND
0120 DVDND3         .DE $2435    ;HI BYTE OF DIVIDEND
0130 TOTFX1         .DE $2700    ;LO BYTE OF TOTAL MISSION FIXATIONS
0140 TOTFX2         .DE $2701    ;MID BYTE OF TOTAL MISSION FIXATIONS
0150 TOTFX3         .DE $2702    ;HI BYTE OF TOTAL MISSION FIXATIONS
0160 TODWL1         .DE $2703    ;LO BYTE OF TOTAL MISSION DWELL TIME
0170 TODWL2         .DE $2704    ;MID BYTE OF TOTAL MISSION DWELL TIME
0180 TODWL3         .DE $2705    ;HI BYTE OF TOTAL MISSION DWELL TIME
0190 CONVE          .DE $21E3    ;CONVERT TO FP
0200 FPOUT          .DE $2340    ;PRINT FP RESULT
0210 SPACE          .BY ' '
0220 OUTCHR         .DE $8A47    ;OUTPUT A CHARACTER
0230 ZEROFX         .DS 1        ;SET TO ZERO IF FIXATIONS=0
0240 ZERODL         .DS 1        ;SET TO ZERO IF DWELL TIME=0
0250 ZEROUT         .BY '+0.0000000E+00'
0251 COUNT          .DS 1
0260 ;
0270 ;ROUTINE TO PRINT OUT RESULTS FOR THE INSTS IN TABLE1
0280 RESTB          TYA
0290                PHA  ;SAVE Y ON STACK
0300                LDA #$FF
0310                STA ZEROFX
0320                STA ZERODL
0330                TXA  ;PRINT OUT THE TOTAL
0340                CLC  ;NUMBER OF FIXATIONS
0350                ADC #31
0360                TAY
0370                LDA ($2D),Y  ;LO BYTE OF FIXATIONS
0380                STA NUM1
0390                INY
0400                LDA ($2D),Y
0410                STA NUM2
0420                LDA #00
0430                STA NUM3
0440                LDA NUM1     ;SEE IF NUMBER OF
0450                BNE NOZER1   ; FIXATIONS = 0
0460                LDA NUM2
0470                BNE NOZER1
```

```
0480              LDA NUM3
0490              BNE NOZER1
0500              LDA #00        ;IF SO, PRINT OUT ZEROS
0510              STA ZEROFX
0520              JSR PRZERO
0530              JMP NEXT1
0540  NOZER1      TXA
0550              PHA
0551              TYA
0552              PHA
0560              JSR CONVE
0570              JSR FPOUT      ;PRINT RESULT
0571              PLA
0572              TAY
0580              PLA
0590              TAX
0600  NEXT1       LDA SPACE
0610              JSR OUTCHR     ;PRINT A SPACE
0620              TXA  ;PRINT OUT TOTAL
0630              CLC  ; DWELL TIME
0640              ADC #28
0650              TAY
0660              LDA ($2D),Y    ;DWELL TIME FOR INST
0670              STA NUM1
0680              INY
0690              LDA ($2D),Y    ;MID BYTE OF DWELL TIME
0700              STA NUM2
0710              INY
0720              LDA ($2D),Y    ;HI BYTE OF DWELL TIME
0730              STA NUM3
0740              LDA NUM1       ;SEE IF DWELL TIME
0750              BNE NOZER2     ; IS ZERO
0760              LDA NUM2
0770              BNE NOZER2
0780              LDA NUM3
0790              BNE NOZER2
0800              LDA #00        ;IF SO, PRINT OUT ZEROS
0810              STA ZERODL
0820              JSR PRZERO
0830              JMP NEXT2
0840  NOZER2      TXA
0850              PHA
0851              TYA
0852              PHA
0860              JSR CONVE
0870              JSR FPOUT      ;PRINT RESULT
0871              PLA
0872              TAY
0880              PLA
0890              TAX
0900  NEXT2       LDA SPACE
0910              JSR OUTCHR     ;PRINT A SPACE
0920  ;PRINT MEAN DWELL TIME=DWELL TIME/NUM OF FIXATIONS
0930              TXA
0940              CLC
```

```
0950            ADC #28
0960            TAY
0970            LDA ZERODL
0980            BNE NOZER3   ;JUMP IF RESULT NOT ZERO
0981            LDA ZEROFX
0982            BNE NOZER3
0990            JSR PRZERO   ;PRINT OUT ZEROS
1000            JMP NEXT3
1010  NOZER3    LDA ($2D),Y  ;LOW BYTE OF DWELL TIME
1020            STA DVDND1
1030            INY
1040            LDA ($2D),Y  ;MID BYTE OF DWELL TIME
1050            STA DVDND2
1060            INY
1070            LDA ($2D),Y  ;HI BYTE OF DWELL TIME
1080            STA DVDND3
1090            INY
1100            LDA ($2D),Y  ;LO BYTE OF NUMBER OF FIXATIONS
1110            STA DIVIS1
1120            INY
1130            LDA ($2D),Y  ;HI BYTE OF NUMBER OF FIXATIONS
1140            STA DIVIS2
1150            LDA #00
1160            STA DIVIS3
1170            JSR PRINT    ;DWELL TIME/NUM OF FIXATIONS-
1180            ;OUTPUT RESULT IN FP
1190  NEXT3     LDA SPACE
1200            JSR OUTCHR   ;PRINT A SPACE
1210  ;PRINT PROPORTION OF TOTAL TIME=DWELL TIME/TOTAL MISSION
1220  ;DWELL TIME
1230            TXA
1240            CLC
1250            ADC #28
1260            TAY
1270            LDA ZERODL
1280            BNE NOZER4
1290            JSR PRZERO
1300            JMP NEXT4
1310  NOZER4    LDA ($2D),Y  ;LO BYTE OF DWELL TIME
1320            STA DVDND1
1330            INY
1340            LDA ($2D),Y  ;MID BYTE OF DWELL TIME
1350            STA DVDND2
1360            INY
1370            LDA ($2D),Y  ;HI BYTE OF DWELL TIME
1380            STA DVDND3
1390            LDA TODWL1   ;PUT TOTAL MISSION
1400            STA DIVIS1   ; DWELL TIME INTO
1410            LDA TODWL2   ; THE DIVISOR
1420            STA DIVIS2
1430            LDA TODWL3
1440            STA DIVIS3
1450            JSR PRINT    ;DWELL TIME/TOTAL MISSION DWELL TIME-
1460            ;RESULT PRINT IN FP FORMAT
1470  NEXT4     LDA SPACE
```

```
1480              JSR OUTCHR    ;PRINT A SPACE
1490     ;PRINT PERCENTAGE OF TOTAL FIXATIONS=NUM OF FIXATIONS/
1500     ;TOTAL MISSION FIXATIONS
1510              TXA
1520              CLC
1530              ADC #31
1540              TAY
1550              LDA ZEROFX
1560              BNE NOZER5
1570              JSR PRZERO
1580              JMP NEXT5
1590     NOZER5   LDA ($2D),Y  ;LOW BYTE OF NUMBER OF FIXATIONS
1600              STA DVDND1
1610              INY
1620              LDA ($2D),Y  ;HIGH BYTE OF NUMBER OF FIXATIONS
1630              STA DVDND2
1640              LDA #00
1650              STA DVDND3
1660              LDA TOTFX1    ;PUT THE TOTAL NUMBER OF
1670              STA DIVIS1    ; FIXATIONS FOR THE
1680              LDA TOTFX2    ; MISSION INTO
1690              STA DIVIS2    ; THE DIVISOR
1700              LDA TOTFX3
1710              STA DIVIS3
1720              JSR PRINT     ;FIXATIONS/TOTAL MISSION FIXATION-
1730              ;PRINT RESULT IN FP FORMAT
1740     NEXT5    PLA
1750              TAY  ;RESTORE Y FROM STACK
1760              RTS
1770     ;SUBROUTINE TO PRINT OUT A ZERO RESULT
1780     PRZERO   TXA
1790              PHA  ;SAVE X REGISTER
1800              LDA #14
1810              STA COUNT
1820              LDX #00
1830     LOOP     LDA ZEROUT,X
1840              JSR OUTCHR    ;PRINT A CHAR
1850              INX
1860              DEC COUNT
1870              BNE LOOP
1880              PLA
1890              TAX  ;RESTORE X
1900              RTS
1910              .EN
```

. Module: Output Second Table

```
>LOAD OUTTC

>PR
 0010                .BA $3500
 0020                .DS
 0030  TRANS         .BY 'TRANSITIONS BETWEEN TWO INSTRUMENTS'
 0040  SOURCE        .BY 'SOURCE'
 0050  BLANK         .BY ' '
 0060  UNDER         .BY '_'
 0070  HEAD1         .BY 'NO DG 01 02 03 04 05 06 07 08 09 10 '
 0080  HEAD2         .BY '11 12 '
 0090  COL           .BY 'GLBLDG0102030405060708091011121314151617181920'
 0100  COL1          .BY '2122232425E'
 0110  TABLE1        .DE $6000
 0120  TABLE2        .DE $6100
 0130  TABLE3        .DE $6200
 0140  TABLE4        .DE $6300
 0150  OUTBYT        .DE $82FA     ;OUTPUT A BYTE
 0160  OUTCHR        .DE $8A47     ;OUTPUT A CHARACTER
 0170  CRLF          .DE $834D     ;CARRIAGE RETURN AND LINE FEED
 0180  COUNT1        .DS 1
 0190  COUNT2        .BY 6
 0200  BINDEC        .DE $39B1
 0210  TEMP          .DS 1
 0220  ;
 0230  ;PRINT OUT HEADER FOR THE SECOND TABLE OF RESULTS
 0240  OUTTC         LDX #00
 0250                LDY #35
 0260                JSR CRLF
 0270  LOOPC         LDA TRANS,X
 0280                JSR OUTCHR    ;PRINT HEADER
 0290                INX
 0300                DEY
 0310                BNE LOOPC
 0320                JSR CRLF
 0330                JSR CRLF
 0340                LDX #00
 0350                LDY #32
 0360  LOOPA         LDA BLANK
 0370                JSR OUTCHR    ;PRINT A SPACE
 0380                DEY
 0390                BNE LOOPA
 0400  LOOPB         LDA SOURCE,X
 0410                JSR OUTCHR    ;PRINT 'SOURCE'
 0420                INX
 0430                DEC COUNT2
 0440                BNE LOOPB
 0450                JSR CRLF
 0460                JSR CRLF      ;SKIP A LINE
 0470                LDX #00
 0480                LDY #00
```

```
LOOP1       LDA BLANK
            JSR OUTCHR    ;PRINT A BLANK
            JSR OUTCHR    ;PRINT A BLANK
            LDA HEAD1,X
            JSR OUTCHR    ;PRINT ONE CHAR OF HEADER
            INX
            LDA HEAD1,X
            JSR OUTCHR    ;PRINT ONE CHAR OF HEADER
            INX
            LDA HEAD1,X
            JSR OUTCHR    ;PRINT OUT ONE CHAR OF HEADER
            INX
            INY
            CPY #14
            BNE LOOP1
            LDY #00       ;DEFINES LOCATION ON COL
            LDX #70
            JSR CRLF
LOOPU       LDA UNDER
            JSR OUTCHR    ;UNDERLINE THE HEADER
            DEX
            BNE LOOPU
            JSR CRLF
            LDX #00
OUTLO1      LDA #13
            STA COUNT1
            JSR CRLF      ;GO TO NEXT LINE
            JSR OUTBG     ;OUTPUT BEGINNING OF ROW
VLOOP1      JSR VOUT1     ;PRINT DATA FOR AN INST
            DEC COUNT1
            BNE VLOOP1
            CPX #$D9
            BEQ NEXT2     ;GO TO NEXT TABLE
            TXA
            CLC
            ADC #21       ;GO TO NEXT INST IN TABLE
            TAX  ;GO TO NEXT INST
            JMP OUTLO1
NEXT2       LDX #00
OUTLO2      LDA #13
            STA COUNT1    ;REINITIALIZE COUNT1
            JSR CRLF      ;GO TO NEXT LINE
            JSR OUTBG     ;PRINT OUT COLUMN HEADER
VLOOP2      JSR VOUT2     ;PRINT ROW FOR AN INST
            DEC COUNT1
            BNE VLOOP2
            CPX #$D9
            BEQ NEXT3     ;GO TO NEXT TABLE IF DONE WITH THIS ONE
            TXA
            CLC
            ADC #21       ;GO TO NEXT INST IN TABLE
            TAX
            JMP OUTLO2
NEXT3       LDX #00
OUTLO3      LDA #13
```

```
                STA COUNT1     ;REINITIALIZE COUNT1
                JSR CRLF       ;GO TO NEXT LINE
                JSR OUTBG      ;PRINT OUT COLUMN HEADER
VLOOP3          JSR VOUT3      ;PRINT OUT A ROW FOR AN INST
                DEC COUNT1
                BNE VLOOP3
                CPX #$D9
                BEQ NEXT4      ;GO TO NEXT TABLE IF DONE WITH THIS ONE
                TXA
                CLC
                ADC #21        ;GO TO NEXT INST IN TABLE
                TAX
                JMP OUTLO3
NEXT4           LDX #00
OUTLO4          LDA #13
                STA COUNT1     ;REINITIALIZE COUNT1
                JSR CRLF       ;GO TO NEXT LINE
                JSR OUTBG      ;PRINT OUT COLUMN HEADER
VLOOP4          JSR VOUT4      ;PRINT ROW FOR AN INST
                DEC COUNT1
                BNE VLOOP4
                CPX #$D9
                BEQ NEXT5      ;DONE WITH THE FOUR TABLES IF DONE WITH THIS ONE
                TXA
                CLC
                ADC #21        ;GO TO NEXT INST IN TABLE
                TAX
                JMP OUTLO4
NEXT5           RTS
;
OUTBG           LDA BLANK
                JSR OUTCHR     ;PRINT A BLANK
                JSR OUTCHR     ;PRINT A BLANK
                LDA COL,Y
                JSR OUTCHR     ;PRINT OUT COLUMN HEADER
                INY
                LDA COL,Y
                JSR OUTCHR
                INY
                LDA BLANK
                JSR OUTCHR
                RTS
;
VOUT1           LDA TABLE1,X
                STA TEMP
                TYA
                PHA  ;PUT INDEX Y ON STACK
                TXA
                PHA
                LDA TEMP
                JSR BINDEC     ;CONVERT NUMBER TO DECIMAL
                JSR OUTBYT     ;PRINT HI BYTE OF DECIMAL NO
                TYA
                JSR OUTBYT     ;PRINT LO BYTE OF DECIMAL NO
                LDA BLANK
```

```
                JSR OUTCHR   ;PRINT A BLANK
                PLA
                TAX
                PLA
                TAY  ;RESTORE INDEX Y FROM STACK
                INX
                RTS
;
VOUT2           LDA TABLE2,X
                STA TEMP
                TYA
                PHA  ;PUT INDEX Y ON STACK
                TXA
                PHA
                LDA TEMP
                JSR BINDEC   ;CONVERT NUMBER TO DECIMAL
                JSR OUTBYT   ;PRINT HI BYTE OF DECIMAL NO
                TYA
                JSR OUTBYT   ;PRINT LO BYTE OF DECIMAL NO
                LDA BLANK
                JSR OUTCHR   ;PRINT A BLANK
                PLA
                TAX
                PLA
                TAY  ;RESTORE INDEX Y FROM STACK
                INX
                RTS
;
VOUT3           LDA TABLE3,X
                STA TEMP
                TYA
                PHA  ;PUT INDEX Y ON STACK
                TXA
                PHA
                LDA TEMP
                JSR BINDEC   ;CONVERT NUMBER TO DECIMAL
                JSR OUTBYT   ;PRINT HI BYTE OF DECIMAL NO
                TYA
                JSR OUTBYT   ;PRINT LO BYTE OF DECIMAL NO
                LDA BLANK
                JSR OUTCHR   ;PRINT A BLANK
                PLA
                TAX
                PLA
                TAY  ;RESTORE INDEX Y FROM STACK
                INX
                RTS
;
VOUT4           LDA TABLE4,X
                STA TEMP
                TYA
                PHA  ;PUT INDEX Y ON STACK
                TXA
                PHA
                LDA TEMP
```

```
2140          JSR BINDEC    ;CONVERT NUMBER TO DECIMAL
2150          JSR OUTBYT    ;PRINT HI BYTE OF DECIMAL NO
2160          TYA
2170          JSR OUTBYT    ;PRINT LO BYTE OF DECIMAL NO
2180          LDA BLANK
2190          JSR OUTCHR    ;PRINT A BLANK
2200          PLA
2210          TAX
2220          PLA
2230          TAY   ;RESTORE INDEX Y FROM STACK
2240          INX
2250          RTS
2260          .EN
```

22. **Module: Output Third Table.**

```
>LOAD OUTTD

>PR
0010                .BA $3750
0020                .OS
0030 BLANK          .BY ' '
0040 UNDER          .BY '_'
0050 HEAD1          .BY 'NO 13 14 15 16 17 18 19 20 21 22 23 '
0060 HEAD2          .BY '24 25 '
0070 COL            .BY 'GLBLD60102030405060708091011121314151617181920'
0080 COL1           .BY '2122232425E'
0090 TABLE1         .DE $6000
0100 TABLE2         .DE $6100
0110 TABLE3         .DE $6200
0120 TABLE4         .DE $6300
0130 OUTBYT         .DE $82FA     ;OUTPUT A BYTE
0140 OUTCHR         .DE $8A47     ;OUTPUT A CHARACTER
0150 CRLF           .DE $834D     ;CARRIAGE RETURN AND LINE FEED
0160 COUNT1         .DS 1
0170 BINDEC         .DE $39B1
0180 TEMP           .DS 1
0190 ;
0200 ;PRINT OUT HEADER FOR THE SECOND TABLE OF RESULTS
0210 OUTTD          JSR CRLF
0220                JSR CRLF
0230                JSR CRLF      ;SKIP A LINE
0240                LDX #00
0250                LDY #00
0260 LOOP1          LDA BLANK
0270                JSR OUTCHR    ;PRINT A BLANK
0280                JSR OUTCHR    ;PRINT A BLANK
0290                LDA HEAD1,X
0300                JSR OUTCHR    ;PRINT ONE CHAR OF HEADER
0310                INX
0320                LDA HEAD1,X
0330                JSR OUTCHR    ;PRINT ONE CHAR OF HEADER
0340                INX
0350                LDA HEAD1,X
0360                JSR OUTCHR    ;PRINT OUT ONE CHAR OF HEADER
0370                INX
0380                INY
0390                CPY #14
0400                BNE LOOP1
0410                LDY #00       ;DEFINES LOCATION ON COL
0420                LDX #70
0430                JSR CRLF
0440 LOOPU          LDA UNDER
0450                JSR OUTCHR    ;UNDERLINE THE HEADER
0460                DEX
0470                BNE LOOPU
```

```
                JSR CRLF
                LDX #$0D
OUTLO1          LDA #13
                STA COUNT1
                JSR CRLF        ;GO TO NEXT LINE
                JSR OUTBG       ;OUTPUT BEGINNING OF ROW
VLOOP1          JSR VOUT1       ;PRINT DATA FOR AN INST
                DEC COUNT1
                BNE VLOOP1
                CPX #$E6
                BEQ NEXT2       ;GO TO NEXT TABLE
                TXA
                CLC
                ADC #21         ;GO TO NEXT INST IN TABLE
                TAX  ;GO TO NEXT INST
                JMP OUTLO1
NEXT2           LDX #$0D
OUTLO2          LDA #13
                STA COUNT1      ;REINITIALIZE COUNT1
                JSR CRLF        ;GO TO NEXT LINE
                JSR OUTBG       ;PRINT OUT COLUMN HEADER
VLOOP2          JSR VOUT2       ;PRINT ROW FOR AN INST
                DEC COUNT1
                BNE VLOOP2
                CPX #$E6
                BEQ NEXT3       ;GO TO NEXT TABLE IF DONE WITH THIS ONE
                TXA
                CLC
                ADC #21         ;GO TO NEXT INST IN TABLE
                TAX
                JMP OUTLO2
NEXT3           LDX #$0D
OUTLO3          LDA #13
                STA COUNT1      ;REINITIALIZE COUNT1
                JSR CRLF        ;GO TO NEXT LINE
                JSR OUTBG       ;PRINT OUT COLUMN HEADER
VLOOP3          JSR VOUT3       ;PRINT OUT A ROW FOR AN INST
                DEC COUNT1
                BNE VLOOP3
                CPX #$E6
                BEQ NEXT4       ;GO TO NEXT TABLE IF DONE WITH THIS ONE
                TXA
                CLC
                ADC #21         ;GO TO NEXT INST IN TABLE
                TAX
                JMP OUTLO3
NEXT4           LDX #$0D
OUTLO4          LDA #13
                STA COUNT1      ;REINITIALIZE COUNT1
                JSR CRLF        ;GO TO NEXT LINE
                JSR OUTBG       ;PRINT OUT COLUMN HEADER
VLOOP4          JSR VOUT4       ;PRINT ROW FOR AN INST
                DEC COUNT1
                BNE VLOOP4
                CPX #$E6
```

```
1030            BEQ NEXT5     ;DONE WITH THE FOUR TABLES IF DONE WITH THIS ONE
1040            TXA
1050            CLC
1060            ADC #21       ;GO TO NEXT INST IN TABLE
1070            TAX
1080            JMP OUTLO4
1090  NEXT5     RTS
1100  ;
1110  OUTBG     LDA BLANK
1120            JSR OUTCHR    ;PRINT A BLANK
1130            JSR OUTCHR    ;PRINT A BLANK
1140            LDA COL,Y
1150            JSR OUTCHR    ;PRINT OUT COLUMN HEADER
1160            INY
1170            LDA COL,Y
1180            JSR OUTCHR
1190            INY
1200            LDA BLANK
1210            JSR OUTCHR
1220            RTS
1230  ;
1240  VOUT1     LDA TABLE1,X
1250            STA TEMP
1260            TYA
1270            PHA  ;PUT INDEX Y ON STACK
1280            TXA
1290            PHA
1300            LDA TEMP
1310            JSR BINDEC    ;CONVERT NUMBER TO DECIMAL
1320            JSR OUTBYT    ;PRINT HI BYTE OF DECIMAL NO
1330            TYA
1340            JSR OUTBYT    ;PRINT LO BYTE OF DECIMAL NO
1350            LDA BLANK
1360            JSR OUTCHR    ;PRINT A BLANK
1370            PLA
1380            TAX
1390            PLA
1400            TAY  ;RESTORE INDEX Y FROM STACK
1410            INX
1420            RTS
1430  ;
1440  VOUT2     LDA TABLE2,X
1450            STA TEMP
1460            TYA
1470            PHA  ;PUT INDEX Y ON STACK
1480            TXA
1490            PHA
1500            LDA TEMP
1510            JSR BINDEC    ;CONVERT NUMBER TO DECIMAL
1520            JSR OUTBYT    ;PRINT HI BYTE OF DECIMAL NO
1530            TYA
1540            JSR OUTBYT    ;PRINT LO BYTE OF DECIMAL NO
1550            LDA BLANK
1560            JSR OUTCHR    ;PRINT A BLANK
1570            PLA
```

```
               TAX
               PLA
               TAY  ;RESTORE INDEX Y FROM STACK
               INX
               RTS
       ;
       VOUT3   LDA TABLE3,X
               STA TEMP
               TYA
               PHA  ;PUT INDEX Y ON STACK
               TXA
               PHA
               LDA TEMP
               JSR BINDEC   ;CONVERT NUMBER TO DECIMAL
               JSR OUTBYT   ;PRINT HI BYTE OF DECIMAL NO
               TYA
               JSR OUTBYT   ;PRINT LO BYTE OF DECIMAL NO
               LDA BLANK
               JSR OUTCHR   ;PRINT A BLANK
               PLA
               TAX
               PLA
               TAY  ;RESTORE INDEX Y FROM STACK
               INX
               RTS
       ;
       VOUT4   LDA TABLE4,X
               STA TEMP
               TYA
               PHA  ;PUT INDEX Y ON STACK
               TXA
               PHA
               LDA TEMP
               JSR BINDEC   ;CONVERT NUMBER TO DECIMAL
               JSR OUTBYT   ;PRINT HI BYTE OF DECIMAL NO
               TYA
               JSR OUTBYT   ;PRINT LO BYTE OF DECIMAL NO
               LDA BLANK
               JSR OUTCHR   ;PRINT A BLANK
               PLA
               TAX
               PLA
               TAY  ;RESTORE INDEX Y FROM STACK
               INX
               RTS
               .EN
```

24. **Module:** **Convert From Binary to Decimal - called by Output Second Table and Output Third Table modules.**

```
>LOAD BINDEC

>PR
                  .BA $39B0
                  .OS
 ; THIS ROUTINE CONVERTS A ONE BYTE HEX NUMBER TO
 ;A TWO BYTE DECIMAL NUMBER.  THE HEX NUMBER IS IN THE
 ;ACC.  THE HI BYTE OF THE DECIMAL NUMBER IS IN THE
 ;ACC AND THE LOW BYTE IN REGISTER Y
 TEMP             .DS 1          ;TEMPORARY STORAGE
 BINDEC           LDY #$FF       ;START QUOTIENT AT -1
                  SEC  ;SET CARRY FOR INITIAL SUBTRACTION
 D100LP           INY  ;ADD 1 TO QUOTIENT
                  SBC #100       ;SUBTRACT 100
                  BCS D100LP     ;BRANCH IF A IS STILL LARGER THAN 100
                  ADC #100       ;ADD THE LAST 100 BACK
                  TAX  ;SAVE REMAINDER
                  TYA
                  PHA  ;SAVE 100'S DIGIT ON THE STACK
                  TXA  ;GET REMAINDER
 ; CALCULATE 10'S AND 1'S DIGITS. DIVIDE REMAINDER
 ;OF THE 100'S DIGIT BY 10.
 ;Y = 10'S DIGIT
 ;A = 1'S DIGIT
                  LDY #$FF       ;START QUOTIENT AT -1
                  SEC  ;SET CARRY FOR INITIAL SUBTRACTION
 D10LP            INY  ;ADD 1 TO QUOTIENT
                  SBC #10
                  BCS D10LP      ;BRANCH IF A IS STILL LARGER THAN 10
                  ADC #10        ;ADD THE LAST 10 BACK
 ;COMBINE 1'S AND 10'S DIGITS
                  STA TEMP
                  TYA
                  ASL A
                  ASL A
                  ASL A
                  ASL A          ;MOVE 10'S TO HIGH NIBBLE OF A
                  ORA TEMP       ;OR IN THE 1'S DIGIT
 ;RETURN WITH Y = LOW BYTE A = HIGH BYTE
                  TAY  ;PLACE IN REG Y
                  PLA  ;GET 100'S DIGIT
                  RTS
                  .EN
```

25. Module: Print Results.

```
>LOAD FINAL

>PR
 0010                .BA $39F0
 0020                .OS
 0030  ; THIS ROUTINE WILL PRINT OUT THE FINAL THREE TABLES
 0040  OUTTC         .DE $3591     ;FIRST TABLE THAT PRINTS OUT TRANSITIONS
 0050  ;BETWEEN INSTRUMENTS
 0060  OUTTD         .DE $37B7     ;SECOND TABLE THAT PRINTS OUT TRANSITIONS
 0070  ;BETWEEN INSTRUMENTS
 0080  TOVAL         .DE $2706     ;ADD UP TOTAL MISIION FIXATIONS AND
 0090  ;TOTAL MISSION DWELL TIME
 0100  OUTPT1        .DE $2915     ;PRINT OUT HEADER FOR FIRST TABLE
 0110  OUTTB         .DE $2A98     ;PRINT OUT BODY OF FIRST TABLE
 0120  FINAL         JSR TOVAL
 0130                JSR OUTPT1
 0140                JSR OUTTB
 0160                JSR OUTTC
 0170                JSR OUTTD
 0180                RTS
 0190                .EN
```

APPENDIX E

Module Validation Data

This appendix shows the data used to test each module or portion of a module. A "$" in front of a number means that number is in base 16.

1. Division subroutine for Add Timing

Table 5

Division Validation Data

Dividend	Divisor	Quotient	Remainder
60000	1000	60	0
60000	50	1200	0
50000	300	16	200
60000	90	666	60

2. Module Add Timing

Table 6

Add Timing Validation Data

Number of Sample	Number of Time Intervals Hexidecimal			Decimal	Num of Intervals Since Last Sample
01	00	00	11	17	
02	00	00	23	35	18
03	00	00	35	53	18
04	00	00	48	72	19
05	00	00	5A	90	18
06	00	00	6C	108	18
07	00	00	7E	126	18
08	00	00	91	145	19
09	00	00	A3	163	18
$0A	00	00	B5	181	18
$0B	00	00	C6	198	17
$0C	00	00	DA	218	20
$0D	00	00	EC	236	18
$0E	00	00	FE	254	18
$0F	00	01	0F	271	17
$10	00	01	21	289	18
$11	00	01	33	307	18
$12	00	01	46	326	19
$13	00	01	58	344	18
$14	00	01	6A	362	18

3. Module Determine Instrument Number

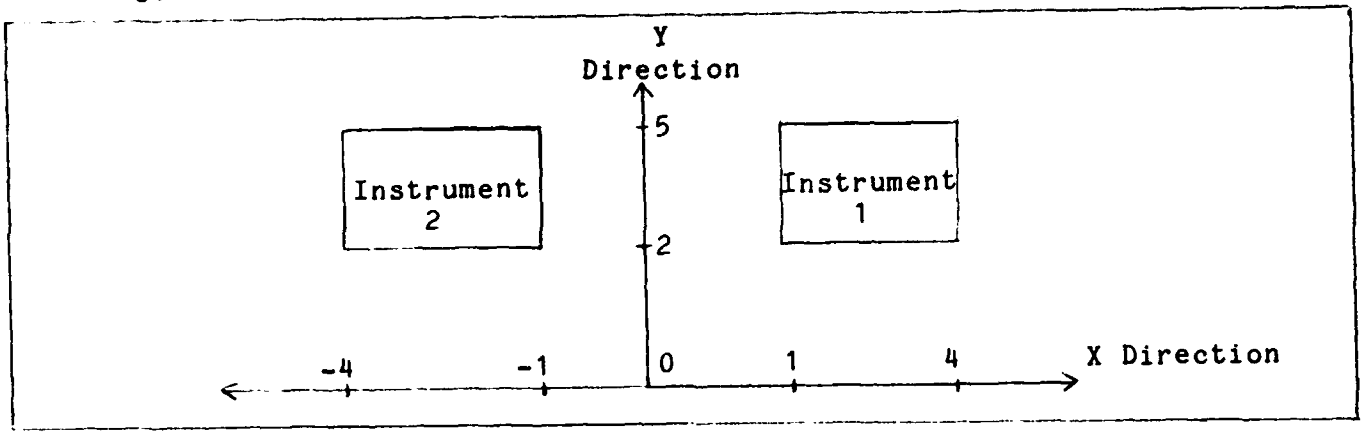


Fig. 6. Test Instrument Boundaries

Table 7

Determine Instrument Number Validation Data

X eye direction	Y eye direction	Instrument Number
2	3	01
5	3	No instrument
6	3	No instrument
-2	3	02
-2	6	No instrument
16383	3	No instrument
1	3	No instrument
4	3	01
-1	3	02
-4	3	No instrument
0	0	No instrument
3	2	No instrument
3	5	01

4. Module Compare Data Samples

Table 8

Compare Data Samples Validation Data

Input Data Samples		Output	
Instrument Number	Data Sample Time(Hexidecimal)	Instrument Number	Total Time On Inst(Hexidecimal)
1st test:			
01	00 00 11	00	00 00 11
01	00 00 22		
01	00 00 33		
02	00 00 44	01	00 00 33
02	00 00 55		
03	00 00 66	02	00 00 11
01	00 00 77		
01	00 00 88		
03	00 00 99	01	00 00 22
2nd test:			
$10	00 00 14	00	00 00 14
05	00 01 11	10	00 00 FD
05	00 01 A1		
03	01 CF 00	05	01 CD EF
03	02 00 00		
03	02 11 01		
$AA	02 11 A1	03	00 42 A1
$AA	02 11 C0		
01	0C D0 54	AA	0A BE BC
02	0C D0 64	01	00 00 10

5. Module Create Table

Table 9

Create Table Validation Data

Inst Number	Total Time On Inst(Hexidecimal)	Last Instrument (Determined by Create Table)
Test 1:		
01	00 00 31	00
01	00 00 33	00
00	00 00 B6	01
00	00 00 B8	01
10	00 00 FC	00
13	00 11 00	10
20	00 00 CD	13
10	00 01 00	20
Test 2:		
11	00 00 FF	00
11	00 01 11	11
11	00 00 20	11
00	00 00 CC	11
22	00 20 14	00
23	00 20 14	22
24	00 30 14	23
19	00 32 00	24
12	00 A0 00	19
Test 3:		
08	00 8C 00	00
03	00 01 00	08
04	00 04 00	03
02	00 02 00	04
05	00 05 01	02
06	00 00 E6	05
07	00 00 F7	06
09	01 01 11	07
14	01 01 00	09

Table 10

Create Table Validation Results

Starting Mem Location	Consecutive Mem contents (if location between 6000 and 63FF is not listed, it is zero)							
Test 1:								
6000	01	00	00	00	00	00	00	00
6018	00	00	00	00	31	00	00	01
6020	00	00	00	01	00	00	00	00
6038	00	00	00	00	00	00	B6	00
6040	00	01	00	00	00	01	00	00
6060	B8	00	00	01	00	00	01	00
6080	33	00	00	01	00	00	00	00
61A8	00	00	01	00	00	00	00	00
61B8	00	00	00	00	00	00	01	00
61C0	00	00	00	00	00	00	FC	01
61C8	00	02	00	00	00	00	00	00
6228	00	00	00	00	01	00	00	00
6238	00	00	00	00	00	00	CD	11
6340	00	01	00	00	00	00	00	00
Test 2:								
6008	00	00	00	01	00	00	00	00
6018	00	00	00	00	20	00	00	01
6048	00	00	00	00	00	00	00	01
6060	CC	00	00	01	00	00	00	00
61C8	00	00	00	00	01	00	00	00
61D0	00	00	00	00	00	00	00	01
61E8	10	02	00	02	00	00	00	00
6210	00	00	00	01	00	00	00	00
6218	00	00	00	00	00	A0	00	01
6318	01	00	00	00	00	32	00	01
6360	00	00	00	00	00	00	01	00
6380	00	00	14	20	00	01	00	00
6398	00	00	00	00	00	00	01	00
63A0	00	00	00	00	14	20	00	01
63C0	00	01	00	00	00	00	14	30
63C8	00	01	00	00	00	00	00	00

Test 3

6088	00	00	00	00	01	00	00	00
60A0	00	00	00	00	00	02	00	01
60B0	00	00	01	00	00	00	00	00
60C0	00	00	00	00	00	00	00	01
60C8	00	01	00	00	00	00	00	01
60E8	00	04	00	01	00	00	00	00
6100	00	00	01	00	00	00	00	00
6118	00	00	00	00	01	05	00	01
6120	00	00	00	00	00	00	00	01
6138	00	00	00	00	00	00	E6	00
6140	00	01	00	00	00	00	00	00
6148	00	00	01	00	00	00	00	00
6160	F7	00	00	01	00	00	01	00
6180	00	00	00	8C	00	01	00	00
6188	00	00	00	00	00	00	00	01
61A0	00	00	00	00	11	01	01	01
6248	00	00	00	00	00	01	00	00
6260	00	01	01	01	00	00	00	00

Appendix F

<u>Simulated Oculometer Input for Subsystem Validation</u>

Track/Out-of Track Status	X Eye Direction (hex)	Y Eye Direction (hex)
Test 1:		
01	00 3C	01 2C
01	00 3C	01 2C
01	00 04	01 2C
01	00 04	01 2C
01	00 04	01 2C
01	00 04	01 2C
01	00 04	01 2C
01	00 04	01 2C
01	00 04	01 2C
01	00 00	01 90
01	00 00	01 90
01	00 00	01 90
01	FF 9C	01 3C
01	FF 9C	00 3C
01	FF 9C	00 3C
01	FF 9C	00 3C
01	FF 9C	00 3C
01	FF 9C	00 3C
01	FF 9C	00 3C
00	FF 9C	00 3C
00	FF 9C	00 3C
00	FF 9C	00 3C
01	FF 9C	00 64
01	FF 9C	00 64
01	FF 9C	00 64
01	FF 9C	00 64
01	FE D4	00 C8
01	FE D4	00 C8
01	FE D4	00 C8
01	FE D4	01 2C
01	FE D4	00 2C
01	FE D4	01 2C
01	FE D4	01 2C
01	FE D4	01 2C
01	FE D4	01 2C
01	00 00	01 90
01	00 00	01 90
01	00 00	01 90
01	00 00	01 90

01	00 00	00 90
01	00 64	00 64
01	00 64	00 64
01	00 64	00 64
01	00 64	00 64
00	00 01	00 01

Test 2:

01	FF 38	01 90
01	FF 38	01 90
01	FF 38	01 90
01	FF 38	01 90
01	00 64	01 DB
01	00 64	01 DB
01	00 64	01 DB
01	00 64	01 DB
01	00 64	01 DB
01	00 C8	00 7D
01	00 C8	00 7D
01	00 C8	00 7D
01	00 C8	00 7D
01	00 C8	00 7D
01	00 C8	00 7D
01	01 90	00 64
01	01 90	00 64
01	01 90	00 64
00	01 90	00 3C
00	01 90	00 3C
01	FF 9C	01 2C
01	FF 9C	01 2C
01	FF 9C	01 2C
01	FF 9C	01 2C
01	00 64	01 E0
01	00 64	01 E0
01	00 64	01 E0
01	00 64	01 E0
01	00 64	01 DB
01	00 64	01 DB
01	00 64	01 DB
01	00 64	01 DB

APPENDIX G

Final Data Tables and Outputs

1. The following are the results of Test 1 inputs of Appendix F.

   a. Final Data Table in memory locations 6000 (hex) to 6400 (hex).

```
.[illegible] 6000.6400
6000 01 00 00 00 00 00 00 00.01
6008 00 00 00 00 00 00 00 00.01
6010 00 00 00 00 00 00 00 00.01
6018 00 00 00 00 11 00 00 01.13
6020 00 00 00 00 00 00 00 01.14
6028 00 00 00 00 00 00 00 00.14
6030 00 00 00 00 00 00 00 00.14
6038 00 00 00 00 00 00 37 00.4B
6040 00 01 00 00 00 00 00 00.4C
6048 00 00 00 00 00 00 00 00.4C
6050 00 00 00 00 00 00 00 00.4C
6058 00 00 00 00 00 00 00 00.4C
6060 00 00 00 00 00 00 01 00.4D
6068 00 00 00 00 00 00 00 00.4D
6070 00 00 00 00 00 00 00 00.4D
6078 00 00 00 00 00 00 00 00.4D
[illegible]80 00 00 90 00 00 01 00 00.DE
6088 00 00 00 00 00 00 00 00.DE
6090 00 00 00 00 00 00 00 00.DE
6098 00 00 00 00 00 00 00 00.DE
60A0 00 00 00 00 00 00 00 00.DE
60A8 00 00 00 00 00 00 01 00.DF
60B0 00 00 00 00 00 00 00 00.DF
60B8 00 00 00 00 00 00 00 00.DF
60C0 00 00 00 00 00 00 6E 00.4D
60C8 00 01 00 00 00 00 00 00.4E
60D0 00 01 00 00 00 00 00 00.4F
60D8 00 00 00 00 00 00 00 00.4F
60E0 00 00 00 00 00 00 00 00.4F
60E8 39 00 00 01 00 00 00 00.89
60F0 00 00 00 00 00 00 00 00.89
60F8 00 00 00 00 00 00 00 00.89
6100 00 00 00 00 00 01 00 00.8A
6108 00 00 00 00 00 00 00 00.8A
6110 00 00 00 00 00 00 00 00.8A
6118 00 01 00 00 CB 00 00 02.58
6120 00 00 00 00 00 00 00 00.58
6128 00 00 00 00 00 00 00 00.58
6130 00 00 00 00 00 00 00 00.58
6138 00 00 00 00 00 00 00 00.58
6140 00 00 00 00 00 00 00 00.58
6148 00 00 00 00 00 00 00 00.58
6[illegible]50 00 00 00 00 00 00 00 00.58
6158 00 00 00 00 00 00 00 00.58
```

```
6160 00 00 00 00 00 00 00 00,58
6168 00 00 00 00 00 00 00 00,58
6170 00 00 00 00 00 00 00 00,58
6178 00 00 00 00 00 00 00 00,58
6180 00 00 00 00 00 00 00 00,58
6188 00 00 00 00 00 00 00 00,58
6190 00 00 00 00 00 00 00 00,58
6198 00 00 00 00 00 00 00 00,58
61A0 00 00 00 00 00 00 00 00,58
61A8 00 00 00 00 00 00 00 00,58
61B0 00 00 00 00 00 00 00 00,58
61B8 00 00 00 00 00 00 00 00,58
61C0 00 00 00 00 00 00 00 00,58
61C8 00 00 00 00 00 00 00 00,58
61D0 00 00 00 00 00 00 00 00,58
61D8 00 00 00 00 00 00 00 00,58
61E0 00 00 00 00 00 00 00 00,58
61E8 00 00 00 00 00 00 00 00,58
61F0 00 00 00 00 00 00 00 00,58
61F8 00 00 00 00 00 00 00 00,58
6200 00 00 00 00 00 00 00 00,58
6208 00 00 00 00 00 00 00 00,58
6210 00 00 00 00 00 00 00 00,58
6218 00 00 00 00 00 00 00 00,58
6220 00 00 00 00 00 00 00 00,58
6228 00 00 00 00 00 00 00 00,58
6230 00 00 00 00 00 00 00 00,58
6238 00 00 00 00 00 00 00 00,58
  40 00 00 00 00 00 00 00 00,58
6248 00 00 00 00 00 00 00 00,58
6250 00 00 00 00 00 00 00 00,58
6258 00 00 00 00 00 00 00 00,58
6260 00 00 00 00 00 00 00 00,58
6268 00 00 00 00 00 00 00 00,58
6270 00 00 00 00 00 00 00 00,58
6278 00 00 00 00 00 00 00 00,58
6280 00 00 00 00 00 00 00 00,58
6288 00 00 00 00 00 00 00 00,58
6290 00 00 00 00 00 00 00 00,58
6298 00 00 00 00 00 00 00 00,58
62A0 00 00 00 00 00 00 00 00,58
62A8 00 00 00 00 00 00 00 00,58
62B0 00 00 00 00 00 00 00 00,58
62B8 00 00 00 00 00 00 00 00,58
62C0 00 00 00 00 00 00 00 00,58
62C8 00 00 00 00 00 00 00 00,58
62D0 00 00 00 00 00 00 00 00,58
62D8 00 00 00 00 00 00 00 00,58
62E0 00 00 00 00 00 00 00 00,58
62E8 00 00 00 00 00 00 00 00,58
62F0 00 00 00 00 00 00 00 00,58
62F8 00 00 00 00 00 00 00 00,58
6300 00 00 00 00 00 00 00 00,58
6308 00 00 00 00 00 00 00 00,58
  10 00 00 00 00 00 00 00 00,58
```

```
6318 00 00 00 00 00 00 00 00,58
6320 00 00 00 00 00 00 00 00,58
6328 00 00 00 00 00 00 00 00,58
6330 00 00 00 00 00 00 00 00,58
6338 00 00 00 00 00 00 00 00,58
6340 00 00 00 00 00 00 00 00,58
6348 00 00 00 00 00 00 00 00,58
6350 00 00 00 00 00 00 00 00,58
6358 00 00 00 00 00 00 00 00,58
6360 00 00 00 00 00 00 00 00,58
6368 00 00 00 00 00 00 00 00,58
6370 00 00 00 00 00 00 00 00,58
6378 00 00 00 00 00 00 00 00,58
6380 00 00 00 00 00 00 00 00,58
6388 00 00 00 00 00 00 00 00,58
6390 00 00 00 00 00 00 00 00,58
6398 00 00 00 00 00 00 00 00,58
63A0 00 00 00 00 00 00 00 00,58
63A8 00 00 00 00 00 00 00 00,58
63B0 00 00 00 00 00 00 00 00,58
63B8 00 00 00 00 00 00 00 00,58
63C0 00 00 00 00 00 00 00 00,58
63C8 00 00 00 00 00 01 00 01,5A
63D0 00 00 00 00 00 00 00 00,5A
63D8 00 00 00 00 00 00 00 00,5A
63E0 00 00 00 00 00 00 00 00,5A
63E8 FB 00 00 02 00 00 00 00,57
63F0 00 00 00 00 00 00 00 00,57
  F8 00 00 00 00 00 00 00 00,57
```

b. Output of first table.

```
>RUN FINAL

TOTAL NUMBER OF FIXATIONS IN THE DATA MISSION=  +0.7001953E+01
TOTAL DWELL TIME IN THE DATA MISSION=  +0.7650545E+03
```

INST NUM	TOTAL NUMBER OF FIXATIONS	TOTAL DWELL TIME	MEAN DWELL TIME	PROPORTION OF TOTAL TIME	PROPORTION OF TOTAL FIXATION
GLIT	+0.1945312E+01	+0.1735938E+02	+0.1735938E+02	+0.2269199E-01	+0.2142857E+00
BLNK	+0.1000000E+01	+0.5500001E+02	+0.5521876E+02	+0.724469E-01	+0.1428571E+00
DAGN	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
01	+0.1000000E+01	+0.1440000E+03	+0.1442500E+03	+0.1885621E+00	+0.1428571E+00
02	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
03	+0.1000000E+01	+0.1100000E+03	+0.1103281E+03	+0.1447304E+00	+0.1428571E+00
04	+0.1000000E+01	+0.5699999E+02	+0.5764064E+02	+0.748366E-01	+0.1428571E+00
05	+0.2000000E+01	+0.2029999E+03	+0.1019140E+03	+0.2656454E+00	+0.2857142E+00
06	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
07	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
08	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
09	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
10	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
11	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
12	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
13	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
14	+0.0000000E+00	+0.0000000F+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
15	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
16	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
17	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
18	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
19	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
20	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
21	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
22	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
23	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
24	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
25	+0.2000000E+01	+0.2510000E+03	+0.1256757E+03	+0.3282884E+00	+0.2857142E+00

c. Output of second table.

TRANSITIONS BETWEEN TWO INSTRUMENTS

						SOURCE							
NO	DG	01	02	03	04	05	06	07	08	09	10	11	12
GL	0001	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
BL	0000	0000	0000	0000	0000	0001	0000	0000	0000	0000	0000	0000	0000
DG	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
01	0001	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
02	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
03	0000	0000	0000	0000	0001	0000	0000	0000	0000	0000	0000	0000	0000
04	0000	0000	0000	0000	0000	0001	0000	0000	0000	0000	0000	0000	0000
05	0000	0000	0000	0000	0000	0001	0000	0000	0000	0000	0000	0000	0000
06	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
07	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
08	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
09	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
10	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
11	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
12	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
13	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
4	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
15	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
16	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
17	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
18	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
19	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
20	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
21	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
22	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
23	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
24	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
25	0000	0001	0000	0001	0000	0000	0000	0000	0000	0000	0000	0000	0000

d. Output of third table.

NO	13	14	15	16	17	18	19	20	21	22	23	24	25
GL	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
BL	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
DG	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
01	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
02	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
03	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
04	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
05	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0001
06	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
07	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
08	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
09	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
10	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
11	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
12	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
13	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
14	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
15	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
16	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
17	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
18	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
19	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
20	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
21	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
22	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
23	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
24	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
25	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000

2. The following are the results of Test 2 inputs of Appendix F.

a. Final Data Table in memory locations 6000 (hex) to 6400 (hex)

```
.V 6000.6400
6000 01 00 00 00 00 00 00 00.01
6008 00 00 00 00 00 00 00 00.01
6010 00 00 00 00 00 00 00 00.01
6018 00 01 00 00 36 00 00 02.3A
6020 00 00 00 00 00 00 00 00.3A
6028 00 00 00 00 00 00 00 00.3A
6030 00 00 00 00 00 00 00 00.3A
6038 00 00 00 00 00 00 00 00.3A
6040 00 00 00 00 00 00 00 00.3A
6048 00 00 00 00 00 00 00 00.3A
6050 00 00 00 00 00 00 00 00.3A
6058 00 00 00 00 00 00 00 00.3A
6060 00 00 00 00 00 00 00 00.3A
6068 00 00 00 00 00 00 00 00.3A
6070 00 00 00 00 00 00 00 00.3A
6078 00 00 00 00 00 00 00 00.3A
6[illegible]0 00 00 00 00 00 00 00 00.3A
6[illegible]8 01 00 00 00 00 00 00 00.3B
6090 00 00 00 00 00 00 00 00.3B
6098 00 00 00 00 00 00 00 00.3B
60A0 00 00 00 00 49 00 00 01.85
60A8 00 00 00 00 00 00 00 00.85
60B0 00 00 00 00 00 00 00 00.85
60B8 00 00 00 00 00 00 00 00.85
60C0 00 00 00 00 00 00 00 00.85
60C8 00 00 00 00 00 00 00 00.85
60D0 00 00 00 00 00 00 00 00.85
60D8 00 00 00 00 00 00 00 00.85
60E0 00 00 00 00 00 00 00 00.85
60E8 00 00 00 00 00 00 00 00.85
60F0 00 00 00 00 00 00 00 00.85
60F8 00 00 00 00 00 00 00 00.85
6100 00 00 00 00 00 00 00 00.85
6108 00 00 00 00 00 00 00 00.85
6110 00 00 00 00 00 00 00 00.85
6118 00 00 00 00 00 00 00 00.85
6120 00 00 00 00 01 00 00 00.86
6128 00 00 00 00 00 00 00 00.86
6130 00 00 00 00 00 00 00 00.86
6138 00 00 00 01 00 00 F7 00.7E
6140 00 02 00 00 00 00 00 00.80
6148 00 00 01 00 00 00 00 00.81
[illegible]50 00 00 00 00 00 00 00 00.81
6158 00 00 00 00 00 00 00 00.81
```

```
6160 72 00 00 01 00 00 00 00.F4
6168 00 00 00 00 00 00 00 00.F4
6170 00 00 00 00 00 00 00 00.F4
6178 00 00 00 00 00 00 00 00.F4
6180 00 00 00 00 00 00 00 00.F4
6188 00 00 00 00 00 00 00 00.F4
6190 00 00 00 00 00 00 00 00.F4
6198 00 00 00 00 00 00 00 00.F4
61A0 00 00 00 00 00 00 00 00.F4
61A8 00 00 00 00 00 00 00 00.F4
61B0 00 00 00 00 00 00 00 00.F4
61B8 00 00 00 00 00 00 00 00.F4
61C0 00 00 00 00 00 00 00 00.F4
61C8 00 00 00 00 00 00 00 00.F4
61D0 00 00 00 00 00 00 00 00.F4
61D8 00 00 00 00 00 00 00 00.F4
61E0 00 00 00 00 00 00 00 00.F4
61E8 00 00 00 00 00 00 00 00.F4
61F0 00 00 00 00 00 00 00 00.F4
61F8 00 00 00 00 00 00 00 00.F4
6200 00 00 00 00 00 00 00 00.F4
6208 00 00 00 00 00 00 00 00.F4
6210 00 00 00 00 00 00 00 00.F4
6218 00 00 00 00 00 00 00 00.F4
6220 00 00 00 00 00 00 00 00.F4
6228 00 00 00 00 00 00 00 00.F4
6230 00 00 00 00 00 00 00 00.F4
6238 00 00 00 00 00 00 00 00.F4
6240 00 00 00 00 00 00 00 00.F4
6248 00 00 00 00 00 00 00 00.F4
6250 00 00 00 00 00 00 00 00.F4
6258 00 00 00 00 00 00 00 00.F4
6260 00 00 00 00 00 00 00 00.F4
6268 00 00 00 00 00 00 00 00.F4
6270 00 00 00 00 00 00 00 00.F4
6278 00 00 00 00 00 00 00 00.F4
6280 00 00 00 00 00 00 00 00.F4
6288 00 00 00 00 00 00 00 00.F4
6290 00 00 00 00 00 00 00 00.F4
6298 00 00 00 00 00 00 00 00.F4
62A0 00 00 00 00 00 00 00 00.F4
62A8 00 00 00 00 00 00 00 00.F4
62B0 00 00 00 00 00 00 00 00.F4
62B8 00 00 00 00 00 00 00 00.F4
62C0 00 00 00 00 00 00 00 00.F4
62C8 00 00 00 00 00 00 00 00.F4
62D0 00 00 00 00 00 00 00 00.F4
62D8 00 00 00 00 00 00 00 00.F4
62E0 00 00 00 00 00 00 00 00.F4
62E8 00 00 00 00 00 00 00 00.F4
62F0 00 00 00 00 00 00 00 00.F4
62F8 00 00 00 00 00 00 00 00.F4
6300 00 00 00 00 00 00 00 00.F4
6308 00 00 00 00 00 00 00 00.F4
6310 00 00 00 00 00 00 00 00.F4
```

6 :18	00	00	00	00	00	00	00	00•F4
6 0	00	00	00	00	00	00	00	00•F4
6 28	00	00	00	00	00	00	00	00•F4
6 30	00	00	00	00	00	00	00	00•F4
6 38	00	00	00	00	00	00	00	00•F4
6 :40	00	00	00	00	00	00	00	00•F4
6 :48	00	00	00	00	00	00	00	00•F4
6 :50	00	00	00	00	00	00	00	00•F4
6 :58	00	00	00	00	00	00	00	00•F4
6 :60	00	00	00	00	00	00	00	00•F4
6 :68	00	00	00	00	00	00	00	00•F4
6 :70	00	00	00	00	00	00	00	00•F4
6 :78	00	00	00	00	00	00	00	00•F4
6 :80	00	00	00	00	00	00	00	00•F4
6 :88	00	00	00	00	00	00	00	00•F4
6 :90	00	00	00	00	00	00	00	00•F4
6 :98	00	00	00	00	00	00	00	00•F4
6 :A0	00	00	00	00	00	00	00	00•F4
6 :A8	00	00	00	00	00	00	00	00•F4
6 :B0	00	00	00	00	00	00	00	00•F4
6 :B8	00	00	00	00	00	00	00	00•F4
6 :C0	00	00	00	00	00	00	00	00•F4
6 :C8	00	00	00	00	00	00	00	00•F4
6 :D0	00	00	00	01	00	00	00	00•F5
6 :D8	00	00	00	00	00	00	00	00•F5
6 :E0	00	00	00	00	00	01	00	00•F6
6 :E8	84	00	00	02	00	00	00	00•7C
6 :F0	00	00	00	00	00	00	00	00•7C
8	00	00	00	00	00	00	00	00•7C

b. Output of first table.

```
>RUN FINAL

TOTAL NUMBER OF FIXATIONS IN THE DATA MISSION=  +0.6001952E+01
TOTAL DWELL TIME IN THE DATA MISSION=  +0.5667657E+03
```

IN T NUM	TOTAL NUMBER OF FIXATIONS	TOTAL DWELL TIME	MEAN DWELL TIME	PROPORTION OF TOTAL TIME	PROPORTION OF TOTAL FIXATION
GLIT	+0.2250000E+01	+0.5475000E+02	+0.2710937E+02	+0.964829E-01	+0.3333334E+00
BLNK	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
DASH	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
01	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
02	+0.1000000E+01	+0.7299999E+02	+0.7348437E+02	+0.1291547E+00	+0.1666667E+00
03	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
04	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
05	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
06	+0.2000000E+01	+0.2469999E+03	+0.1237812E+03	+0.4363957E+00	+0.3333334E+00
07	+0.1000000E+01	+0.1139999E+03	+0.1145625E+03	+0.2016894E+00	+0.1666667E+00
08	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
09	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
10	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
11	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
12	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
13	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
14	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
15	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
16	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
17	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
18	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
19	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
20	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
21	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
22	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
23	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
24	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00	+0.0000000E+00
25	+0.2000000E+01	+0.1320000E+03	+0.6649219E+02	+0.2342645E+00	+0.3333334E+00

Output of second table.

TRANSITIONS BETWEEN TWO INSTRUMENTS

SOURCE

NO	DG	01	02	03	04	05	06	07	08	09	10	11	12
GL	0001	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
BL	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
DG	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
01	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
02	0001	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
03	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
04	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
05	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
06	0000	0000	0001	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
07	0000	0000	0000	0000	0000	0000	0001	0000	0000	0000	0000	0000	0000
08	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
09	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
10	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
11	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
12	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
13	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
14	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
15	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
16	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
17	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
18	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
19	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
20	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
21	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
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J. Output of third table.

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RL	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
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VITA

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Oculometer
SYM-1
6502 Assembly Language

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A SYM-1 microprocessor with dual 5-1/4 inch disk drives was used to develop software to gather and reduce data from a Cubic-Foot Remote Oculometer built by Honeywell, Inc. The primary function of the oculometer is to measure the look direction of a pilot's eye in a ground cockpit simulator. The output of the oculometer used for this effort is eye

lookpoint in azimuth and elevation and whether the oculometer is tracking the eye or not. The line-of-sight measurement covers a viewing field of plus and minus 30 degrees in azimuth and zero to plus 30 degrees in elevation. This viewing field is broken into instruments whose boundaries are defined by the data collection subsystem.

~~The following~~ performance measures are printed out at the end of the data missions.

1. Total dwell time on each instrument.
2. Mean dwell time on each instrument.
3. Proportion of dwell time on each instrument.
4. Proportion of fixations on each instrument.
5. Transition probability from one instrument to another.
6. Number of fixes per minute for each instrument.

The software for the SYM-1 was developed modularly with each module tested separately and then the whole subsystem tested. Simulated oculometer data was used to test the software. The data collection subsystem was designed to run with minimal knowledge and interaction required by the user.